

Master thesis for the Master of Economics degree

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# Housing Market in Norway

*An Econometric analysis of housing market using q-theory of housing investment*

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## Preface

I would like to thanks my supervisor Håvard Hungnes for his insightful supervision and all the help that he has offered me while writing this thesis. I really appreciate the way in which he has explained the things to me, his encouragement and patience while clarifying the concept that I did not understand. I would also like to thank Torbjørn Eika who spent time while studying my paper and gave me his precious comments. In addition I am also thankful to Ådne Cappelen, who have thrust trust upon me and let me into SSB.

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# 1. Introduction

The interaction of the housing market with the wider economy has been seen as an important mechanism by which macroeconomic factors are expressed and transmitted.

Housing market is an important component of total private investment, playing a significant role in business cycles. It is also an important sector for the financial side of the economy, labour market, construction industry and policy making.<sup>1</sup> Thus, the working of the housing market is of great importance for the economy and it needs to be analysed thoroughly.

The growth in house prices has been very significant in Norway in the last few decades. Figure 1 shows the rising pattern of house prices over time (quarterly prices from 1970-2005). House prices have risen by over 50% since 1993.<sup>2</sup> This increase in house price has caused housing investment to increase as well.

Due to the huge upswing in house prices, housing investment has also increased significantly. “According to figures for the building industry, housing starts came about 31,600 in 2005, which represent a 5.4 percent increase on the previous year. By way of comparison, the increase was as high as 29.4 percent in 2004. The upswing has continued into 2006, and preliminary figures show that housing starts are 4.8 percent higher in the first four months of this year compared with the same period one year earlier. According to the preliminary national accounts figures, housing investment expanded by 14.5 percent in 2005 supported by strong growth in real income and lower real interest rates. The strong housing start figures at the end of 2005 and the beginning of 2006 point to a sustained, high level of housing investment again in 2006”.<sup>3</sup>

Different reasons have been given for the rising house prices in most of the developed European countries including Norway. This unusual upswing in house prices and housing starts have motivated me to analyse the housing market in Norway. Since housing market is

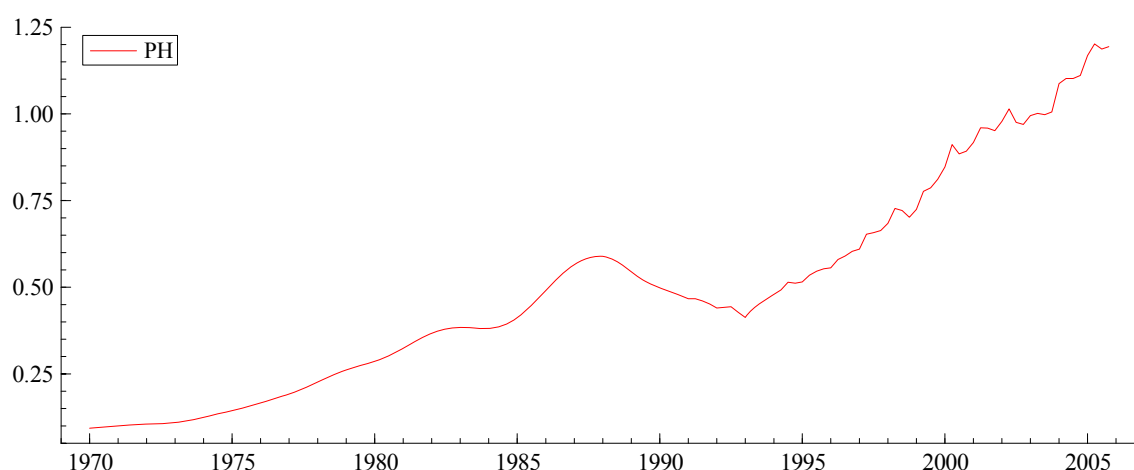
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<sup>1</sup> Since Central Bank targets inflation and design policies according to the situation of the economy, monetary policy takes into account the demand pressure that comes from the housing market (housing demand).

<sup>2</sup> See KVARTS databank, Statistics Norway

<sup>3</sup> See Statistics Norway (2006), Economic Survey 2/2006, pp 6-7

**Figure 1:** The rising pattern of house prices over time



*Source: Statistics Norway*

an important sector for major industries and policy making, it is important to know which factors affect this industry.

Thus, the primary objective of this paper is to model real house prices and investment. We want to know how the existing housing stock affects housing investment decision, and what other factors determine housing investment. Apart from this we also want to know the determinants of housing demand, hence house prices.

The paper models the housing market in Norway for the sample period 1973-2005 using Tobin's q-theory of housing investment and an error correction model (ECM). The q-theory of housing investment identifies the factors that may cause fluctuations in the market value of the housing stock. Using these factors, I will try to find out which of these factors affect the housing investment in Norway most and are responsible for the cyclical behaviour of housing market. In this regard, I consider both the supply and demand side of the housing market separately. This distinction is necessary because, unlike many other goods, production represents an increment to an existing stock of housing capital, while demand for housing can be either for the asset, or for the implied flow of services derived from living in a house. The paper also takes into account the structural breaks that can affect the housing market, like credit market deregulation in the mid 1980s and tax reforms in 1992. The paper also estimates short and long term elasticity and the error correction speed of adjustment coefficients. The model, estimated over the period 1973-2005, consists of a system with an

inverted housing demand equation and an investment supply equation. The results and the diagnostic tests indicate that the model specification is satisfactory. The estimations and tests are carried out using PCGIVE 10.<sup>4</sup>

The secondary objective of the paper is to investigate if changes in house prices can be predicted? I.e. can the stock flow model be used for forecasting and can it beat a random walk model?

Using the model and running the data in PCGIVE 10, we find out that among all determinants of housing demand and supply, interest rate and housing stock are the two variables that affect both sides of the housing market. The other significant determinants of housing demand are real house prices, and real disposable income. The supply side is most affected by investment in housing market and house price relative to construction cost. Among all the significant variables, some are significant either in short run or long run, while others are in both cases. Apart from that, the regression results show that demand side fit better the model compared to the supply side. This is evident from the R-square of the two sides.

The study is structured in the following sections: Section 2 presents a review of some earlier studies. Section 3 represents the theoretical considerations for modelling the real house prices in Norway. Section 4 deals with the ECM methodology applied in the study. Section 5 presents the empirical results on house prices and investment functions for Norway. Section 6 presents the forecasting evaluation of Norway. A comparison with naïve auto-regressive alternatives is carried out. Section 7 concludes.

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<sup>4</sup> See Hendry and Doornik (2001)

## 2. Review of Some Earlier Studies

House prices are commonly derived as a reduced form from separate housing demand and supply equations. Westway and Pain (1996) derive their house price equation from the marginal rate of substitution condition relating the consumption goods and housing services in an intertemporal optimising model. They have conditioned the demand side equation on consumption than income (i.e. consumption is used as a proxy for income).

Another study on Sweden is by Hort (1997) using a dynamic capital asset market model in which an ECM estimates real house prices as a function of total income, user and construction costs. Barot (2001), models Swedish house prices using a simple demand and supply econometric model and finds similar to Hort that house prices can be traced back to demand and supply conditions. In addition Barot illustrates that the Swedish model can be used for both short and medium term forecasting.

Norges Bank (2004) reports a model for house prices using ECM. The sample period is 1990-2004 and quarterly data has been used. The model contains effects of the housing stock, the unemployment rate, bank's lending rates after taxes, total wage income in the economy and an indicator of household expectations concerning their own financial situation and the Norwegian economy. Among the results, it found no evidence that demographic conditions have a strong impact on house prices as a whole. Jacobsen and Naug (2005) have modelled a price index for resale homes as a whole in order to know whether there is a bubble in the housing market. They found no evidence that house prices are overvalued compared with a fundamental value determined by interest rates, income, unemployment and housing construction. Boug, Dyvi, Johansen and Naug (2002) have used two reduced form equations for housing stock and real house prices (for existing houses) in order to investigate relationship between housing stock, house prices and housing consumption. Both housing stock and house price for existing houses are function of household's real disposable income, real interest rate after taxes and real house price for new houses.

### 3. Theoretical Considerations

According to the standard analysis of housing demand, a house is both a good, in that it produces valuable flow of housing services, and an asset, in the sense that it is a durable good which can be resold in a future date. Assuming housing services are a normal good; *flow* demand is decreasing in its relative price and increasing in household income. This flow demand is then converted into a desired stock of housing, by assuming that services vary proportionally with the stock.<sup>5</sup>

Households derive utility from consumption and the flow of housing services that can be acquired either by owning a house or by renting it. These two tenure alternatives, for simplicity, are assumed to provide perfectly substitutable services in an amount equal to the size of the dwelling.

The price of housing services differs from the purchase price. For household that rent, it is simply the rent paid. Households that own their own home incur a user cost.<sup>6</sup>

In contrast to demand side, housing supply is necessarily specified in terms of the flow of new investment. Profit maximizing firms will have a positive supply response to selling prices for structures, and a negative response to their own costs, including interest rates.<sup>7</sup>

Since housing market is described in terms of stock and flow of new investment, and housing is an asset as well as the source of a service flow, we therefore allow for the existence of both stock and flow markets (existing housing and new construction respectively) so disequilibria persist unless both markets are in equilibrium. The stock flow model of the housing market is motivated by a concern with business cycles and forecasting, see Barot (2001).<sup>8</sup>

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<sup>5</sup> See Henderson and Ioannides (1986)

<sup>6</sup> The user cost includes the cost of maintenance and depreciation, plus the opportunity cost of not investing in some other asset with a nominal return, partly offset by the expected rate of capital gain or loss on housing.

<sup>7</sup> See Sørensen and Jacobsen (2005)

<sup>8</sup> The term stock refers to the outstanding stock of structures, for which demand and supply interact to determine asset prices. The term flow refers to the rate of new construction, which is determined by profit potential as measured by the rate of asset prices to construction costs (Tobin's  $q$ )



In this regard, fluctuations in house prices have been analysed in terms of an inverted demand function for houses, conditional on last period's housing stock. In the short term, the housing stock is taken as fixed and all increase in supply comes from new construction, i.e. housing starts. In the long run it evolves as new construction, maintenance and depreciation of the older stock takes place.

We will model housing investment using the Tobin's  $q$  model and consider both demand and supply sides of housing investment.

### 3.1 A $q$ -theory of housing investment

The standard model of the housing market consists of three equations - a demand equation which given the housing stock, real income, interest rate and so forth determines house prices in the short run, a supply equation which determines the supply of new houses and an equation showing how the stock of houses changes over time as new houses are completed. The house price equation is derived from the demand for housing services by inverting and rearranging the demand equation, so that the dependent variable is house prices as opposed to the quantity of housing services or housing stock.

Housing investment can be explained along lines which are similar to the  $q$ -theory of business investment.<sup>9</sup> Like the  $q$ -theory of business investment, the theory of housing investment also shows that investment varies negatively with interest rate and positively with total income. In order to show this, a theory of housing demand is presented before turning to the supply side of the housing market. The theory of housing demand gives the house price  $P^H$ , which is a function of real interest rate and income. This house price is then used in the equation of housing investment on the supply side of housing market.

#### 3.1.1 *The long run demand for the stock of housing ( $H^D$ )*

Consider a representative consumer who has borrowed to acquire a housing stock  $H$  at the market price  $P^H$  per unit of housing. Let the amount the consumer has to spend on repair and maintenance each period to maintain the value of his house to be  $\delta P^H H$ . Let the real interest rate paid by households on mortgage debt after taxes, be  $r$ .<sup>10</sup>

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<sup>9</sup> See Sørensen and Jacobsen (2005)

<sup>10</sup> Since borrowing and lending rate follow each other, we assume that the variable  $r$  explains both types.

We define  $r$  as:<sup>11</sup>

$$r = \frac{(1 + RPI(1 - RIY))}{\left(\frac{P}{P-1}\right) - 1}$$

where

$RPI$  = Households average interest rate earned by investing in private financial institutions,

$RIY$  = average marginal tax rate on investment income, and

$P$  is consumer price index

The consumer's total cost of housing consumption will then be  $(r + \delta) P^H H$ . The consumer also consumes an amount  $G$  of non-durable goods. If his income is  $Y$ , and if we ignore savings (which will not affect the result qualitatively), the consumer's budget constraint is

$$PG + (r + \delta)P^H H = Y, \quad (3.1)$$

where  $P$  is the price of non durable goods. The consumer wishes to allocate his total consumption between housing and non-durables so as to maximize his utility  $U$  which is assumed to be given by the Cobb-Douglas function:<sup>12</sup>

$$U = H^\eta G^{1-\eta} \quad 0 < \eta < 1 \quad (3.2)$$

In practice, the consumer will derive utility from the housing *service* flowing from the housing stock  $H$ , and not from the housing stock as such. Using the budget constraint (3.1) to eliminate  $G$  from (3.2), we get:

$$U = H^\eta \left[ \frac{Y - (r + \delta)P^H H}{P} \right]^{1-\eta} \quad (3.3)$$

<sup>11</sup> While defining  $r$ , best way is to use house price inflation ( $P^H$ ) instead of using consumer price index ( $P$ ), as user cost of financing a house is affected by  $P^H$  and not by  $P$ . But that could make our estimation unstable, since house prices are following an increasing path constantly over time. An increase in  $P^H$  leads to an increase in housing demand, which further push house price up, implying that the system could follow an explosive path.

<sup>12</sup> The specification in equation (3.2) assumed that the housing service is proportional to the housing stock.

The consumer's optimal level of housing demand is found by maximizing the utility function (3.3) with respect to  $H$ , i.e. by  $dU/dH = 0$ , which gives:

$$\eta H^{\eta-1} \left[ \frac{Y - (r + \delta)P^H H}{P} \right]^{1-\eta} - \frac{(r + \delta)P^H (1 - \eta)H^\eta}{P} \left[ \frac{Y - (r + \delta)P^H H}{P} \right]^{-\eta} = 0 \quad (3.4)$$

Or

$$\frac{\partial U / \partial H}{\partial U / \partial G} = \frac{(r + \delta)P^H}{P} \quad (3.5)$$

Equation (3.5) says that, in optimum, the marginal rate of substitution between housing and non-durables must equal the relative price of housing,  $\frac{(r + \delta)P^H}{P}$ . If we solve (3.4) for  $H$ , we get the *demand for housing*, now denoted as  $H^D$ :

$$H^D = \frac{\eta Y}{(r + \delta)P^H} \quad (3.6)$$

The term  $(r + \delta)P^H$  is sometime referred to as the ***user cost of housing***.<sup>13</sup> We see from (3.6) that housing demand varies positively with income and negatively with the user cost of housing. Even if the consumer has financed the purchase of the house by his past savings, the user cost should still include the interest rate  $r$  as an opportunity cost, since this is the income the consumer forgoes by investing his savings in a house rather than in interest bearing assets.<sup>14</sup>

Using real house prices, we can write (3.6) as

$$H^D = f \left( \underset{+}{Y/P}, \underset{-}{P^H/P}, \underset{-}{r} \right) \quad (3.7)$$

<sup>13</sup> The term  $(r + \delta)P^H$  reflects the financial cost,  $r$ , as well as the cost of maintenance, captured by the parameter  $\delta$  which may be seen as a depreciation rate for housing capital.

<sup>14</sup> Also, if the consumer expects a capital gain on his house due to a rise in house price, this gain should be subtracted from the total user cost. However, we abstract from the expected capital gains, as expected gains are hard to measure. Also if we consider these gains, we have to use  $P^H$  while calculating  $r$ . That could cause additional problem of an unstable system as explained in footnote 11.

### 3.1.2 The long run supply for the stock of houses ( $H^S$ )

Consider the production function of the construction sector. Suppose that the investment in housing, ( $I^H$ ), is given by the production function:

$$I^H = A.C^\beta \quad 0 < \beta < 1, \quad (3.8)$$

where  $C$  is a composite input factor and  $A$  is a constant that depends on the productive capacity of the construction sector. The assumption that the parameter  $\beta$  is less than 1 implies that production is subject to diminishing returns to scale.

Assume that construction firms combine labour  $L$  and building material  $B^M$  in fixed proportions. Specifically, each unit of the composite input  $C$  includes  $a$  units of labour and  $b$  units of materials:

$$L = aC, \quad B^M = bC \quad (3.9)$$

If  $W$  is the wage rate and  $P^M$  is the price of materials, it follows from (3.9) that the price of a unit of the composite input  $C$ ,  $P^C$ , is equal to

$$P^C = aW + bP^M \quad (3.10)$$

We call  $P^C$  as the ‘construction price index’ and  $P^H$  is the market price of a unit of housing. Then the sales revenue of the representative construction firm will be  $P^H I^H$ , and its profits,  $\Pi$ , will be:

$$\Pi = P^H I^H - P^C C = P^H I^H - P^C \left[ \frac{I^H}{A} \right]^{1/\beta} \quad (3.11)$$

Taking the housing price  $P^H$  and the input price  $P^C$  as given; the construction firm chooses its level of activity  $I^H$  such that its profits is maximised. According to (3.11), the first order condition for profit maximization,  $d\Pi/dI^H = 0$ , implies:

$$P^H - \frac{P^C}{\beta A} \left[ \frac{I^H}{A} \right]^{(1-\beta)/\beta} = 0 \quad \Leftrightarrow$$

$$I^H = k \left( \frac{P^H}{P^C} \right)^{\beta/(1-\beta)} \quad \text{where} \quad k = \beta^{\beta/(1-\beta)} A^{1/(1-\beta)} \quad (3.12)$$

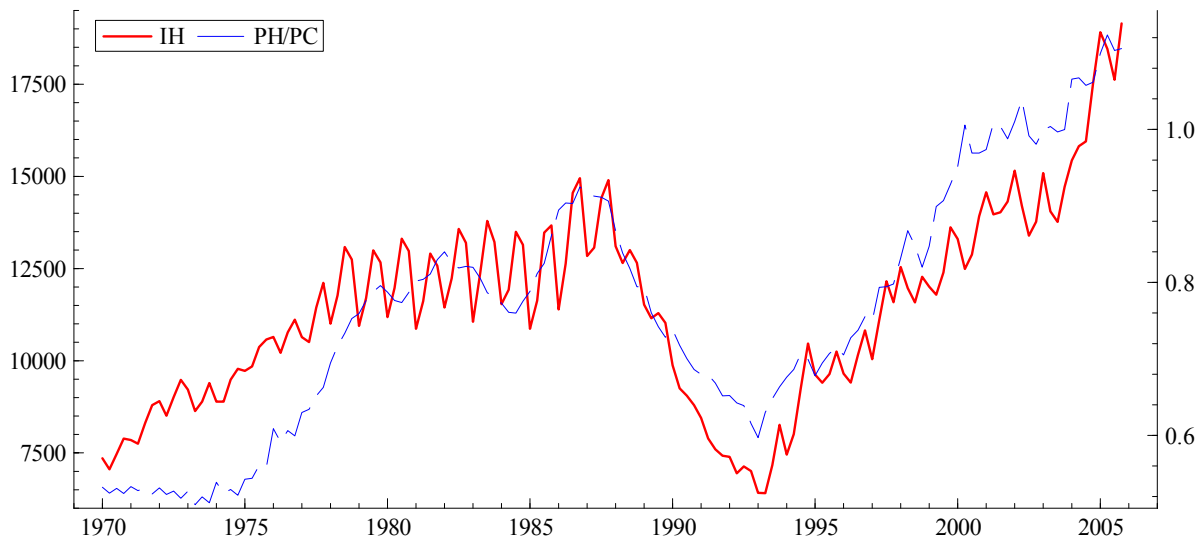
Equation (3.12) is the **supply curve** for the construction sector. According to this equation, profit maximizing construction firms will push construction activity to the point where the marginal construction cost equals the market price of a unit of housing. **Tobin's q** is defined here as an index of market price ( $P^H$ ) to the construction price index ( $P^C$ ):  $q = P^H / P^C$

Since  $0 < \beta < 1$ , equation (3.12) says that housing investment  $I^H$  will be larger the higher the q-ratio of the housing price to the construction price index is. Figure 2 show that this theory of housing investment fits the facts very well for Norway.

Thus, applying Tobin's q theory to the housing market, optimal housing investment is determined by the maximization of profit incentive represented by the ratio of the asset prices of existing structures, to the cost of new construction.

**Figure 2**

Figure shows that housing investment and Tobin's q are strongly positively correlated\*



Source: Statistics Norway

\*Investment in houses in millions NOK (left axis)

House price relative to construction price index (right axis)

In long run equilibrium, the value of Tobin's  $q$  converges to 1, implying that house prices converges towards construction costs, but in the short run  $q$  may vary from 1.<sup>15</sup>

While (3.6) gives the *demand* for housing, the aggregate *supply* of housing is fixed in the short run where the housing stock is predetermined by the accumulated past levels of housing investment. I.e. at the start of each period there is a given housing stock, since the current construction activity determined by (3.12) does not add to the housing stock until the start of next period. In the short run, the market price of houses must therefore adjust to bring the demand for housing  $H^D$  in line with the existing supply,  $H$ .

Inserting the equilibrium condition,  $H^D = H$  into (3.6) and solving for  $P^H$ , we get the *market clearing price* of houses:

$$P^H = \frac{\eta Y}{(r + \delta)H} \quad (3.13)$$

From (3.13), a higher pre-existing housing stock will imply a lower current housing price, given that all other variables are fixed. The housing price will be also be lower the higher the real interest rate  $r$  and the lower the level of income,  $Y$ .<sup>16</sup>

Substituting (3.13) into (3.12) for  $P^H$  will give a housing investment function of the form:

$$I^H = k \left[ \frac{\eta Y}{(r + \delta)P^C H} \right]^{\beta/(1-\beta)}$$

Or more generally:<sup>17</sup>

$$I^H = h \left( \begin{matrix} Y, & H, & r, & P^C \\ + & - & - & - \end{matrix} \right) \quad (3.14)$$

<sup>15</sup> In long run equilibrium, when  $q=1$ , equation (3.12) shows that long run housing investment will be a function of productive capacity and the parameter  $\beta$ .

<sup>16</sup> A rise in interest rate implies a rise in mortgage payment, which in turn will lower housing demand, hence house prices.

<sup>17</sup> Construction cost, such as labour and material would shift the supply curve. A higher interest rate will, ceteris paribus, reduce the market price of housing, hence reduce housing investment.

### 3.1.3 Housing market dynamics

At the aggregate level, part of the current investment in housing,  $I_t^H$ , serves to compensate for the depreciation of the existing housing stock,  $\delta H$ . The housing stock in period  $t$ ,  $H_t$ , and in period  $t+1$ ,  $H_{t+1}$ , is therefore linked by the identity

$$H_{t+1} = H_t(1 - \delta) + I_t^H, \quad (3.15)$$

Equation (3.12), (3.13) and (3.15) constitute a simple dynamic model of the housing market. For given values of  $Y$  and  $r$ , the predetermined housing stock,  $H$ , determines the housing price for period  $t$  via (3.13). Given the value of  $P^C$ , equation (3.12) then determines the current level of housing investment,  $I_t^H$ , which subsequently determines the next period's housing stock  $H_{t+1}$  via (3.15). We then get a new housing price  $P_{t+1}^H$  via (3.13) which enables us to determine  $I_{t+1}^H$  by use of (3.12), giving a new housing stock  $H_{t+2}$  via (3.15) and so on. This dynamic process will continue until the housing price has reached a level where construction activity is just sufficient to compensate for the depreciation of the existing housing stock so that the stock of housing remains constant. Thus, whereas an upward shift in housing demand is fully absorbed by rise in house prices in the short run, over the longer run it will cause an increase in the housing stock which will dampen the initial price increase.

### 3.1.4 Preferred Specification

#### Demand Side:

To obtain sensible results, we have made a little modification to the demand function given by equation (3.7). Instead of using disposable income ( $Y$ ), we use disposable income minus dividends ( $Y^d$ );<sup>18</sup> this is because of tax related adaptations in connection with the change of dividend tax due to which the impact of dividend payments on household demand became negligible. Several changes in taxation of dividends have implied large fluctuations in this income component. This income component and its fluctuations are assumed to have a much smaller influence on household demand than income in general. Therefore we use  $Y^d$  instead of using  $Y$ .

I have also included step dummy variables for credit market deregulation and for tax reform that happened in Norway around 1986 and in 1992 respectively. The rationale behind the

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<sup>18</sup> See Statistics Norway (2006), Economic Survey 1/2006, pp 6.

inclusion of these dummies in our model is the consumption boom in Scandinavia in the 2<sup>nd</sup> half of 1980s; see Berg and Bergstrom (1995). This boom was accompanied by a massive rise in household debt and by an asset price boom in housing market. The factors behind these booms could be: deregulation of credit markets, lifting of foreign exchange controls, and tax reforms. In Norway, credit market deregulation was done in the mid 1980s, whereas the tax reform was done in 1992.<sup>19</sup> Financial deregulation is one important factor behind the increase in wealth over time, after 1985.

Regarding the tax reforms, the objective of the reform was to achieve a moderate taxation of capital income, while maintaining the distributional role of a progressive tax on labour income. The reform was supposed to foster savings, although possibly causing overshooting in savings while consumers adjust to the new tax regime. Thus the inclusion of dummies for these two variables, i.e. the deregulation and the tax reform, helps us to identify any structural break in house prices since the two may have led to the asset price boom.

Apart from this, we also include household debt ( $D$ ) and household's financial wealth ( $W^F$ ) in our model, since the two are important determinants of housing demand.<sup>20</sup> The deregulation of credit markets eased the borrowing constraints on households and probably caused many to increase debts. Also for the debt decision, we assume that only collateralized debt is available, and we impose the existence of borrowing limits at the time of purchasing a house.<sup>21</sup>

Now demand for housing stock can be written as:

$$H^D = f \left( \underset{-}{P^H/P}, \underset{+}{D}, \underset{+}{W^F}, \underset{-}{r}, \underset{+}{Y^d/P} \right) \quad (3.16)$$

An increase in house price or real interest rate, given all other variables, reduces the demand for housing investment.

<sup>19</sup> An unregulated credit market should mean that individuals can discount wealth and future income to a greater extent than under a regulated market regime. The collateral value of different assets becomes relatively more important.

<sup>20</sup> See Barot (2001)

<sup>21</sup> Specifically, a minimum down payment proportional to the value of the house is required, and such a restriction applies irrespectively of the purpose of purchase, i.e. regardless of whether the house will be occupied by the owner or supplied in the rental market.



Solving (3.16) for house prices, we get the inverted demand function:<sup>22</sup>

$$P^H/P = f(H, \underset{-}{D}, \underset{+}{W^F}, \underset{+}{r}, \underset{-}{Y^d/P}) \quad (3.17)$$

( $H^D=H$  in long run)

Equation (3.17) shows that real house prices depend negatively on real interest rate and the housing stock ( $H$ ), and positively on the financial wealth, household debt and real disposable income. A rise e.g. in income first boosts housing demand and thereby raises prices where, housing stock is initially given. Also, a rise in income suggests that current cash flow constraint matters less as credit becomes more easily available, thus increasing the demand for housing.

On the way to long run, if real house prices and hence housing investment begin to diverge from their long run relationships, the three variables ( $D$ ,  $W^F$  and  $Y^d/P$ ), along with the level of real interest rate act in the error correcting mechanism, and drive house prices and housing stock back towards equilibrium.

In the long run, all variables stay at their long run values. This characterizes the steady state of the system where all disequilibrium has been removed.

Along with the inclusion of the above variables, we include real house price ( $P^H/P$ ) and consumer price index ( $P$ ) separately in the short run dynamics. The relative price of housing is one of the long run determinants of house price.<sup>23</sup>

The short term dynamics on the demand side for Norway are represented by the following variables: Yearly changes in the real interest rate and population, the employment rate, household debt, and inflation rate.

Variables that contribute towards long run are included in error correction form but without imposing any restrictions between parameters.

<sup>22</sup> In practice, estimated versions of (3.17) are invariably dynamic- they include lagged house prices and lagged explanatory variables on the right hand side of (3.17) and often include an equilibrium error correction term.

<sup>23</sup> See Barot (2001)

The equation for long run demand in log linear form is then (excluding short run dynamics):<sup>24</sup>

$$\ln (P^H/P) = \beta_0 + \beta_1 \ln (H) + \beta_2 \ln (Y^d/P) + \beta_3 \ln (D) + \beta_4 \ln (W^F) + \beta_5 \ln (E) + \beta_6 r + \beta_7 i + \beta_8 TR + \beta_9 DREG \quad (3.18)$$

where  $TR$  and  $DREG$  are step dummies for tax reform and credit market deregulation respectively. Note that both the interest rates are in absolute level rather than log level. All the parameters except  $\beta_6$  and  $\beta_7$  give the long run elasticity, whereas  $\beta_6$  and  $\beta_7$  gives semi elasticity with respect to real house prices.

#### Supply Side:

On the supply side, we include step dummies for tax reform and credit market deregulation for the same reason as we have done for demand side. We also include housing investment ( $I^H$ ) in the short run dynamics, since it is one of the long run determinants of housing investment.

The short term dynamics on the supply side for Norway are represented by: Yearly changes in the interest rate (both real and nominal), Tobin's  $q$ , housing stock and mainland GDP or total income.

The equation for long run supply in log linear form is then (excluding short run dynamics):

$$\ln (I^H) = \alpha_0 + \alpha_1 \ln (P^H/P^C) + \alpha_2 \ln (I^H/H) + \alpha_3 r + \alpha_4 i + \alpha_5 TR + \alpha_6 DREG \quad (3.19)$$

To take account for the short run effect, we include differenced data in our model. We take fourth difference of the dependent variable and the variables which appear in short run dynamics. This has been done in order to get annual change in all the variables from the quarterly data available. This specification is used for both demand and supply side.

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<sup>24</sup> We have included both nominal and real interest rate as an explanatory variable in order to know that which one of the interest rates is an important determinant of real house price and housing investment.

## 4. Econometric Methodology

Error correction models link equations formulated in levels with those formulated in differences of the original variables. The levels represent the long run while the differences the short term dynamics. An important element in econometrics is the need to combine or relate short run dynamics with long run equilibrium. The analysis of short run dynamics is often done by first eliminating trends in the variables usually by differencing. Explicit attention is paid in this study to the time series properties of the housing data set to form a meaningful model. Thus unit root test is performed.

### 4.1 Error Correction Models (ECM)<sup>25</sup>

In order to elaborate on ECM model and relation between short run and long run, consider the following ADL model:<sup>26</sup>

$$Y_t = \beta_0 + \beta_1 X_t + \beta_2 X_{t-1} + \alpha Y_{t-1} + \varepsilon_t \quad (4.1)$$

In order to know what this equation implies about the long run relationship between  $Y$  and  $X$  (a so-called steady state situation), it is useful to rewrite equation (4.1), so that the relationship between levels and growths becomes clear. The reason to do this is that changes in  $Y_t$  are not only caused by changes in  $X_t$ , but also by last period's deviation between  $Y$  and the steady state equilibrium value of  $Y$ , which we denote as  $Y^*$ .<sup>27</sup> The version of the model which shows this most clearly is known as the error correction model, ECM for short.

To establish the ECM transformation of the ADL, we need to make two algebraic steps. First subtract  $Y_{t-1}$  from both sides of equation (4.1), and then subtract and add  $\beta_1 X_{t-1}$  on the right hand side.

This gives the ECM version of the ADL model:

<sup>25</sup> This section builds on notes by Nymoen (2006)

<sup>26</sup> This kind of model has two properties: first it usually explains the behaviour of the dependent variable much better than a simple static relationship, which imposes on the data that all adjustments of  $Y$  to changes in  $X$  takes place without delay. Second, it allows us to calculate the dynamic multipliers.

<sup>27</sup> The period to period changes in  $Y_t$  are correcting past deviations from equilibrium, as well as responding to new changes in the explanatory variables.

$$\Delta Y_t = \beta_0 + \beta_1 \Delta X_t + (\beta_1 + \beta_2) X_{t-1} + (\alpha - 1) Y_{t-1} + \varepsilon_t \quad (4.2)$$

If  $Y_t$  and  $X_t$  are measured in logarithms (as in our model), then  $\Delta Y_t$  and  $\Delta X_t$  are their respective growth rates. The coefficient of explanatory variable then gives the elasticity.<sup>28</sup>

The occurrence of both a variable's growth rate and its level in one equation is a defining characteristic of ECM model.

Since the disturbance term is the same in (4.1) and (4.2), the transformation is referred to as 1-1 transformation.<sup>29</sup> Hence, if OLS is a valid estimation method of the ADL model, it's also valid for ECM model.

For further interpretation of the dynamic relationship between  $X$  and  $Y$ , it is useful to collect the level terms  $X_{t-1}$  and  $Y_{t-1}$  in equation (4.2) inside a bracket, as follows,

$$\Delta Y_t = \beta_0 + \beta_1 \Delta X_t - (1 - \alpha) \left[ Y - \frac{\beta_1 + \beta_2}{1 - \alpha} X \right]_{t-1} + \varepsilon_t, \quad -1 < \alpha < 1 \quad (4.3)$$

If  $\alpha = 1$ , then the coefficient of  $X$  is infinite and there is no long run relationship between  $Y$  and  $X$ . If  $|\alpha| > 1$ , then the solution of the dynamic model is unstable, i.e. it doesn't turn to its long run equilibrium value after a shock.

Let us assume that in the long run, there is a static relationship between  $X$  and the equilibrium value  $Y$ , i.e.  $Y^*$ ,

$$Y^* = k + \gamma X \quad (4.4)$$

Where,  $k$  and  $\gamma$  are long run parameters,  $\gamma$  being the long run multiplier of  $Y$  with respect to a permanent change in  $X$ . For the ADL model given by equation (4.1), the long run multiplier is  $(\beta_1 + \beta_2) / (1 - \alpha)$ .<sup>30</sup>

Hence, we can identify the slope coefficient  $\gamma$  in the long run as:

<sup>28</sup>I.e. the coefficient is the percentage change in  $Y$  when  $X$  change by 1 percent.

<sup>29</sup>I.e. the statistical properties (e.g. no autocorrelation and heteroscedasticity) of the disturbance term are the same in the original ADL model as in the transformed ECM model.

<sup>30</sup> We get the long run multiplier by setting  $Y_t = Y_{t-1} = Y$  and  $X_t = X_{t-1} = X$  and  $\varepsilon_t = 0$  in equation (4.1). I.e. all variables are at their steady state values and there is no shock in the steady state.

$$\gamma = \frac{\beta_1 + \beta_2}{1 - \alpha}, \quad -1 < \alpha < 1$$

And the expression inside the brackets in (4.3) can be rewritten as:

$$Y - \frac{\beta_1 + \beta_2}{1 - \alpha} X = Y - \gamma X = Y - Y^* + k \quad (4.5)$$

Using (4.5) in (4.3) we get

$$\Delta Y_t = \beta_0 - (1 - \alpha) k + \beta_1 \Delta X_t - (1 - \alpha) \{Y - Y^*\}_{t-1} + \varepsilon_t \quad -1 < \alpha < 1 \quad (4.6)$$

showing that  $\Delta Y_t$  is explained by two factors: first the change in the explanatory variables,  $\Delta X_t$  and second, the correction of the last period's disequilibrium, the deviation between  $Y_{t-1}$  and the last period's equilibrium level  $Y^*$ .

Consider next a steady state. The simplest steady state is a static one. I.e. with no growth, so  $\Delta Y_t = \Delta X_t = 0$ ,  $\varepsilon_t = 0$  and  $\{Y - Y^*\}_{t-1} = 0$  by definition of a steady state.

From (4.6), this gives,  $k = \beta_0 / (1 - \alpha)$ , where  $k$  is the long run relationship. Thus, there is an important correspondence between the dynamic model and a static relationship like (4.4).

In order to discuss the solution of the ADL and see why e.g.  $\alpha = -1$  give rise to unstable solution, assume that both  $X_t$  and  $\varepsilon_t$  are fixed at their respective constant means:

$$\varepsilon_t = 0 \text{ for } t = 0, 1, \dots, \text{ and } X_t = m_x \text{ for } t = 0, 1, \dots$$

Thus the ADL in equation (4.1) as:

$$Y_t = \beta_0 + B m_x + \alpha Y_{t-1} \quad \text{where } B = \beta_1 + \beta_2 \quad (4.7)$$

We assume that equation (4.7) holds for  $t = 0, 1, 2, \dots$ . It is usual to refer to  $t = 0$  as the initial period. The assumption that we make about the initial period is crucial for the existence and uniqueness of a solution. A standard result is the following: if  $Y_0$  is a fixed and known number, then there is a unique sequence of numbers  $Y_0, Y_1, Y_2 \dots$  which is the solution of (4.7).

Solving equation (4.7) by backward induction from known initial condition gives the following general solution:

$$Y_t = (\beta_0 + Bm_X) \sum_{s=0}^{t-1} \alpha^s + \alpha^t Y_0, \quad t = 1, 2, \dots \quad (4.8)$$

When  $-1 < \alpha < 1$ , the solution exists and it is stable. The characteristic of a stable solution is that asymptotically there is no trace left of the initial condition  $Y_0$ . Thus as  $t \rightarrow \infty$ , we have asymptotically:

$$Y^* = \frac{(\beta_0 + Bm_X)}{1 - \alpha}$$

If there is a permanent change in  $X_t$  then

$$\partial Y / \partial m_X = (\beta_1 + \beta_2) / (1 - \alpha),$$

which corresponds to long run multiplier of  $Y_t$  with respect to a permanent change in  $X_t$ .

If the solution is stable, then the dynamic process essentially corrects for the initial discrepancy between the initial level of  $Y$  and its long run level.

If  $\alpha = 1$ , then from (4.8):

$$Y_t = (\beta_0 + B m_X) t + Y_0, \quad t = 1, 2, \dots$$

showing that the solution contains a linear trend and that the initial condition exerts full influence over  $Y_t$  even over infinitely long distances. Thus there is no well defined equilibrium of  $Y_t$ .

Thus, while using the ECM model, and applying it on the data, it is important to check if the model's autoregressive (AR) coefficient is less than 1 in absolute value or not. If not, then there will be no movement towards long run steady state. Equation (4.3) and (4.6) gives the general form of ECM for one explanatory variable. The model can be generalised to more than one explanatory variables and more lags for both dependent and independent variables, as it will be the case in our model.

## 4.2 Integration

A series which is itself non-stationary but which is stationary after first differencing is defined as been integrated of order one i.e. I (1). As a preliminary step to co-integration analysis, the order of integration of the housing model data set is to be tested. Several procedures are available. The most used is Augmented Dickey Fuller (ADF) integration test, which is employed to the log level of the respective variables.<sup>31</sup>

$$\Delta Y_t = \alpha + \gamma t + \delta Y_{t-1} + \beta_1 \Delta Y_{t-1} + \beta_2 \Delta Y_{t-2} + \dots + \beta_s \Delta Y_{t-s} + e_t, \quad (4.9)$$

Where  $Y_t$  is the relevant time series and  $e_t$  is the residual,  $t$  is a linear deterministic time trend and  $s$  is the lag length. One can chose whether to include a constant or constant and trend, and the lag length.

The null and alternative hypothesis is:

$H_0: \delta = 1$  and  $\gamma = 0$  in (4.9)

$H_1: |\delta| < 1$

Tests for unit roots are performed on the Norwegian housing data set employing ADF test. The results of the ADF test indicate that the variables are stationary after first differencing. We conclude that all the variables are integrated of order 1. The results are presented in appendix 2.

## 4.3 Co-Integration

Once it is known that the economic time series data are non-stationary, it is important to uncover the long run relationship between those non stationary variables. Linear combinations of I (1) are usually I (1) as well. However, it may happen that the integration cancels between series and yield I (0) outcome: i.e. a stationary process, this is called co-integration. Engle and Granger (1987) developed the theory of co-integration. The basic idea of co-integration is that individual economic time series wander considerably, but certain linear combinations of the series do not move too far apart from each other. Economic forces tend to bring them into line, e.g. as hypothesized by some economic theory. Departures from long run equilibrium (as given by the theory) induce error correction mechanism (ECM) which moves the economy

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<sup>31</sup> See Hendry and Doornik (2001), pp 44

back to towards its path. Such linear combinations thus remove unit roots and allow stationary inference.

As appendix 2 shows, all the time series are  $I(1)$ . The integration between them cancels to yield  $I(0)$  outcome if the variables are co-integrated. I.e. if  $(1-\alpha)$  in (4.1), (4.2) and (4.3) is significantly different from zero. This will turn the non-stationary process into a stationary one, and our ECM equation will be a balanced one, where all variables are  $I(0)$ . Whether the long run coefficient  $(1-\alpha)$  is significantly different from zero or not will be known when we run our regression on both demand and supply sides.

What is often called balance in the regression is an important property. This means that when the dependent variable is of order zero, the explanatory variables should also be of that order. In models which include explicit error correction terms, this requirement is fulfilled as a consequence of the stationarity of the co-integrating vectors, see Banerjee et al. (1993) and Stock and Watson (1988).

Generally if we have the equation

$$\Delta Y = \alpha_0 + k(Y - \beta X) + \Delta X + \varepsilon,$$

where  $k$  is the coefficient describing the long run relationship between  $Y$  and  $X$ .

If  $Y \sim I(1)$  and  $X \sim I(1)$ , then this implies that  $\Delta Y \sim I(0)$  and  $\Delta X \sim I(0)$  and  $(Y - \beta X) \sim I(0)$  if  $Y$  and  $X$  are co-integrated. Since  $Y$  and  $X$  are  $I(1)$ , the co-integration between them depend only on if  $k$  is significantly different from zero. If that is the case, then the above equation represents a balanced regression where all variables are  $I(0)$ .

## 4.4 Estimation

Our model is dynamic, i.e. it incorporates elements that describe both the short and long run developments. The latter is often included in the form of error correction terms. Since the data is quarterly, we have to take fourth difference of the variables for both demand and supply



side. One of the main aims of using 4<sup>th</sup> differences is to eliminate most of the seasonal variability prior to estimation and also as an aid for interpreting and forecasting short term developments in annual terms. Taking the fourth difference also makes comparison easier quarter wise. E.g. we can compare the house price in first quarter of 1995 with the house price in first quarter of 1996. It is better to compare variables quarter wise rather than annually, since most of the variables that are used in estimating house prices and investment show seasonality. The annual comparison will ignore any seasonal variation present in the variables. However we still include seasonal dummies in our estimation, since we also have to estimate the long run relationship and the variables that represent the long run may have seasonality in them.

The model which is estimated using the fourth difference can be interpreted in the dependent variable as the yearly change in house price being explained by the yearly changes in a broad set of variables representing short term dynamics and the variables in log levels representing the long run.

As the variables are found to be integrated, an error correction model can be formulated. An unrestricted autoregressive distributed lag model (ADL) is finally estimated. This model is then solved numerically for the static long run re-parameterized into ECM form. The ECM here estimates the long run parameters and the short run dynamics jointly.

The general model on the demand side for Norway is over parameterized with lags for house prices, income, wealth and a broad set of explanatory variables (*real and nominal interest rates, household debt, population, employment, inflation rate, financial wealth, housing stock, seasonal dummies and finally the variable that form the ECM term*).

Similarly the general model on the supply side is over parameterized with lags for *investment, housing stock, Tobin's q, GDP and interest rate*.

The equation for demand side to be estimated is:

$$D^4 \ln (P^H/P) = \beta_0 + \beta_1 \ln H_{-4} + \beta_2 \ln (Y^d/P)_{-4} + \beta_3 \ln D_{-4} + \beta_4 \ln WF_{-4} + \beta_5 \ln E_{-4} + \beta_6 r_{-4} + \beta_7 i_{-4} + \beta_8 \ln (P^H/P)_{-4} + \beta_9 TR + \beta_{10} DREG +$$

$$\begin{aligned} & \beta_{11} D^4 \ln (P^H/P)_{-1} + \beta_{12} D^4 \ln (P^H/P)_{-4} + \beta_{13} D^4 \ln (P^H/P)_{-5} + \beta_{14} D^4 \ln (D) + \\ & \beta_{15} D^4 \ln (E) + \beta_{16} D^4 r + \beta_{17} D^4 \ln (P) + \beta_{18} D^4 \ln (POP)_{-5} + \\ & \beta_{19} S + \beta_{20} SI + \beta_{21} S2 \end{aligned} \quad (4.10)$$

The equation for supply side to be estimated is:

$$\begin{aligned} D^4 \ln (I^H) = & \alpha_0 + \alpha_1 \ln (P^H/P^C)_{-4} + \alpha_2 \ln (I^H/H)_{-4} + \alpha_3 r_{-4} + \alpha_4 i_{-4} + \\ & \alpha_5 TR + \alpha_6 DREG + \\ & \alpha_7 D^4 \ln (P^H/P^C) + \alpha_8 D^4 \ln (I^H)_{-1} + \alpha_9 D^4 \ln (I^H)_{-4} + \alpha_{10} D^4 \ln (I^H)_{-5} + \\ & \alpha_{11} D^4 \ln (GDP) + \alpha_{12} D^4 \ln (H)_{-1} + \alpha_{13} D^4 \ln (H)_{-4} + \alpha_{14} D^4 \ln (H)_{-5} + \alpha_{15} D^4 r + \\ & \alpha_{16} D^4 i \\ & \alpha_{17} S + \alpha_{18} SI + \alpha_{19} S2 \end{aligned} \quad (4.11)$$

where  $S$  stands for seasonal dummies.

## 5. Presentation of Results

### 5.1 The demand side of Norway's housing market

The estimated specific model (3.17), given by equation (4.10), including the short run dynamics using the general to specific approach, is reported in appendix 3a, model (3a-1).

As equation (4.10) shows, the initial regression includes 18 explanatory variables, some of which contribute to short run dynamics. However all of these are not significant (as the results show). I have run ten regressions, excluding the insignificant variables one by one, beginning with the least significant one.

In the final regression which is reported in appendix 3a, we have nine explanatory variables, all of which are significant except housing stock and a step dummy for credit market deregulation. We include these two insignificant variables in our final regression because exclusion of these two gives higher variance for the model. The eliminated variables include financial wealth, debt and population. Although population is an important demographic variable, but it's appears to be quite insignificant in our model.

One of the reasons for the insignificant wealth effect can be the fact that people on average are well paid in Norway. So they can easily get loan to buy a house, and hence they don't need ample financial wealth to get a loan. The insignificance of debt in long run can be due to the possibility that the causation run in the opposite direction. I.e. as house prices increase, people need more loan to buy a house, which implies that debt goes up. Thus the causation is from house price to debt, and not the other way round.

The insignificance of these two variables can also be due to the fact that real disposable income is significant in our final regression. Disposable income has been defined as:

$$Y = wL + r_1 W^F - r_2 D - T \quad (T=\text{taxes}, L=\text{hours worked}, w=\text{wage rate})$$

This means that financial wealth and household debt are used twice in the regression. Once, they appear indirectly as a determinant of disposable income, and then also directly in the regression equation. The significance of real disposable income can be due to the inclusion of  $W^F$  and  $D$  in it, thus making the two variables insignificant on their own.

Annual mortgage debt ( $D$ ) is however significant in the short run and it form part of short run dynamics. The short run elasticity for debt is 0.27.

Employment is also insignificant for both dynamics and long run. The unemployment variable reflects uncertainty and it was incorporated into the model as the business cycle factor.

Unemployment practically prevents a worker from entering the house market as a buyer.

Thus, a rise in unemployment gives a negative demand shock to housing demand while a decrease in unemployment produces a positive demand shock. Since people can rent houses, the insignificance of this factor for Norway suggests that either unemployment is very low here or the percentage of people who rent house is more than who buy a house. Thus, the demand for housing can be more because of high demand for renting house as well as for buying it. However, most people in Norway own their house.

The standard error of the final regression is approximately 1.5 % and it explains 95% of the total variation in real house prices. The signs of all of the long and short run dynamic variables in the final regression are in agreement with prior theoretical expectations and they are significant.

The estimated model for real house price is given by:

$$\begin{aligned} D^4 \ln (P^H/P) = & -1.29 + 0.94 D^4 \ln (P^H/P)_{-1} + -0.56 D^4 \ln (P^H/P)_{-4} + 0.39 D^4 \ln (P^H/P)_{-5} \\ & + 0.27 D^4 \ln D - 0.12 [\ln (P^H/P) + 0.33 \ln (H) + 3.31 r - 1.27 \ln (Y^d/P)]_{-4} \\ & + 0.02 S + 0.003 S1 - 0.002 S2 \end{aligned}$$

The expression in square brackets gives the long run relationship between house prices and its explanatory variables (that are significant in the long run). The expression measures the deviation between the house price in the last year and an estimated long term relationship between house prices, housing stock, the real interest rate and real disposable income corrected for dividends.

Note that the condition from (4.3),  $-1 < \alpha < 1$ , is met in our model where  $1 - \alpha = 0.12$ , which implies  $\alpha = 0.88$ .<sup>32</sup> This error correction term is negative and significant. The adjustment coefficient for the level of real house prices ( $P^H/P$ ) indicates that in case of departure from equilibrium, 12 % of the shock is corrected within one year. In case of large disequilibria, the price adjustment process will be more rapid whereas small disequilibria might not be distinguished from noise.

Thus our model meets the stability condition. Starting from a steady state or equilibrium, if a shock hits the system, there will be error correction towards equilibrium. Hence the system will turn to its long run equilibrium value again, once the effect of shock dies out.

The solved long run estimated equation (3.18) on the demand side excluding short run dynamics can be written as:

$$\ln (P^H/P) = -0.0397/0.12 \ln(H) - 0.3966/0.12 r + 0.152/0.12 \ln (Y^d/P)$$

$$\ln (P^H/P) = -0.33 \ln (H) - 3.31 r + 1.27 \ln (Y^d/P) \quad (5.1)$$

Equation (5.1) gives the long run solution for real house price, where the long run elasticity for housing stock is 0.33 and the long run semi elasticity for real interest rate is 3.31.

We have begun our regression by including real interest rate both in short as well as in long run. This was done in order to pick up the dynamics of the interest rate. We cannot include nominal interest rate in the short run since as equation (4.10) shows; inflation rate is also included in the short run dynamics to capture the effect of relative house housing prices. Including both nominal and real interest rate directly would introduce excessive co-linearity in the model. We have included nominal interest rate in the long run; however that appears to be insignificant.

Our final result shows that the change in real interest rate effect real house prices only in the long run. The interest rate has a semi elasticity of 3.31%, i.e. one percentage point increase in

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<sup>32</sup> As the AR coefficient (coefficient for the long run relationship) is significantly different from zero, this implies that the variables which form the long run relationship are co-integrated in levels.

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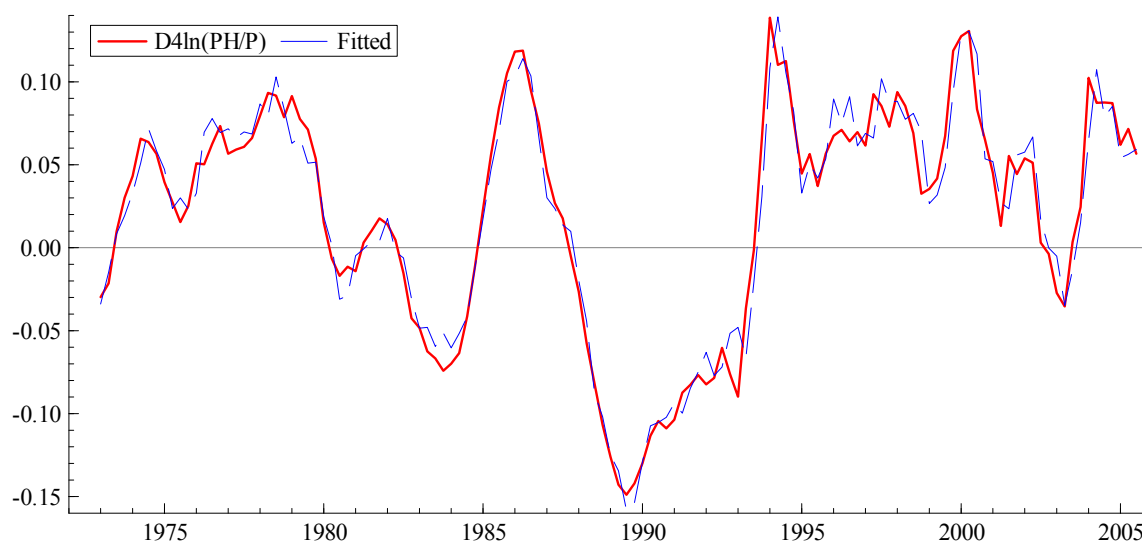
long after tax rate would decrease the real house price by 3.31%. This suggests that housing demand is quite sensitive to interest rate.

One reason for the interest sensitivity of housing demand can be the regulated financial market in the first half of the sample. This tends to confirm the findings of McCarthy and Peach (2002); financial regulations affecting the supply side of the mortgage market resulted in the demand side of the housing being more interest sensitive than if the lending restrictions had not been in place.

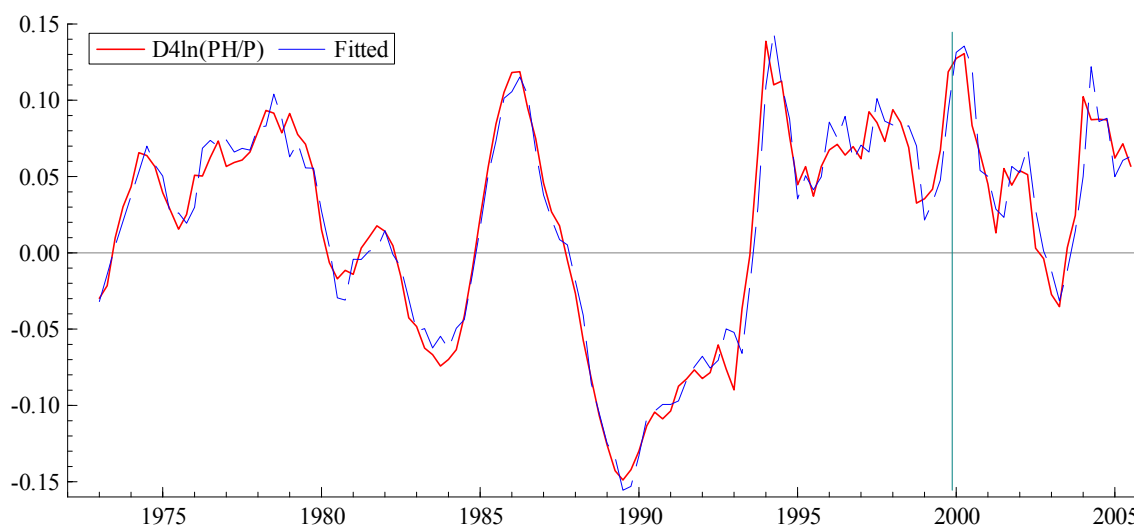
Real disposable income is also significant implying that income plays an important role in determining the demand pressure in economy. As real disposable income increase by 1%, real house price goes up by 1.27%, suggesting a rise in housing demand.

With regard to inflation, a rise in nominal price index also makes housing more expensive. Increased inflation changes the time profile of real mortgage payments. However, CPI or inflation does not significantly form part of short run dynamics in our case. It might be due to the inclusion of CPI in the dependent variable in order to get real house price. Since real house price is significant in the short run, it can make CPI insignificant on its own.

The results show that the model tracks the size and the direction of changes in house prices for owner occupied homes fairly well (see figure 5). The out of sample 1-step forecasts (using data from 1973-2000) for the period 2000-2005 are impressive indicating that house prices are predictable (see figure 6). The model picks up quite well the movements on the demand side of housing market for the sample period.

**Figure 5. Demand Side: Within sample forecast**

As the figure shows, the fitted values closely follow the actual ones, implying that our model tracks the change in real house price quite well.

**Figure 6. Demand Side: Out of sample 1-step forecast 2000-2005**

As the figure shows, in the 1-step forecast, the forecasted values closely follows the actual ones, implying that our forecast is reliable and it predict the value of real house price quite well.

### 5.1.1 Sub samples and variations of demand model:

Appendix 3a presents results for different models. These include the standard model (3a-1), the pure short run models (3a-2)-(3a-3), and sub sample models (3a-4)-(3a-7).<sup>33</sup>

Model (3a-1) is our main model that we are using for analysis of demand side of housing market and for the purpose of forecasting. The other models are used to see what happens with the estimated values and the significance of different variables when the sample includes just the short run dynamics or when the sample size is changed.

In model (3a-2), we include only short run variables as regressors. This gives us all variables as significant except annual change in level of real interest rate. The model is not acceptable due to serially correlated residuals. However inclusion of the lagged dependent variable in the above model eliminates a considerable part of the serial correlation and lowers the parameter estimates of all the other variables. This is done in model (3a-3). But inclusion of lagged values of the dependent variable also causes the DW statistic to be biased towards non rejection of the null hypothesis. Hence in such a case DW close to 2 should not be taken as evidence of non rejection of the null hypothesis. It should also be noted that the inclusion of lagged dependent variable causes model's  $\sigma$  to go down and  $R^2$  to go up. This improvement reflects that additional information is used in model (3a-3), i.e. inclusion of lagged dependent variables. Thus the past values of the dependent variable are crucial in order to have better estimates.

Model (3a-4) is sub sample for period 1973-1985, and model (3a-5) is sub sample for period 1986-2005. The break point is chosen to be 1985, since much of the deregulation of the credit market had taken place at this time. As the results of the two sub-regressions show, nominal interest rate becomes insignificant after deregulation, whereas real interest rate is still significant although its value is less than it was before the deregulation. Also after deregulation, housing stock and financial wealth become insignificant along with CPI or inflation. Real disposable income becomes significant after deregulation, with a positive sign, which is in accordance with economic theory. Annual change in household debt also becomes significant after deregulation. However, both the  $\sigma$  and  $R^2$  of the model (3a-4) seems to suggest that it is better than model (3a-5).

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<sup>33</sup> All these models, i.e. model (3a-4) to model (3a-7) start by including all the variables in the regression that are used initially to get model (3a-1).



Model (3a-6) is sub sample for period 1973-1991, and model (3a-7) is sub sample for period 1992-2005. Year 1992 is selected as the break point because the tax reforms were applied in 1992. As the results show, after the tax reform both real and nominal interest rate becomes significant in the long run along with inflation, employment, household debt and real disposable income. It is interesting to note that none of the long run variables are significant before tax reforms. However, sigma of model (3a-6) is less than model (3a-7) suggesting it to be a good model.

## 5.2 The supply side of Norway's housing market

The estimated dynamic housing investment function, where we model housing investment as a function of Tobin's  $q$  using a dynamic version of equation (3.14), given by (4.11) is presented in appendix 3b; model (3b-1).

As equation (4.11) shows, the initial regression includes 16 explanatory variables, some of which contribute to short run dynamics. However all of these are not significant (as the results show). I have run ten regressions, excluding the insignificant variables one by one, beginning with the least significant one.

In the final regression which is reported in appendix 3b, we have eight explanatory variables, all of which are significant except annual percentage change in GDP. We include this insignificant variable in our final regression because exclusion of this gives higher variance for the model.

We have include both nominal and real interest rate in short run as well as long run in order to know which of the interest rates is more important in determining housing investment.

The standard error of regression is 3.95%, and 84.5% of the total variance in annual change in housing investment is accounted for, thus indicating poorer fit than for the house price equation.<sup>34</sup> The signs of most of the short run dynamics and long run are in agreement with prior theoretical expectations.

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<sup>34</sup> Having  $R^2 = 84.5\%$  is a good measure of fit on its own, it is poorer fit as compared to what we got on demand side of the housing market.

The estimated model for housing investment is given by:

$$\begin{aligned} D^4 \ln(I^H) = & -2.28 + 0.46 D^4 \ln(I^H)_{-1} + 0.32 D^4 \ln(P^H/P^C) + -1.39 D^4 r + 9.12 D^4 \ln H + \\ & 0.14 D^4 \ln(GDP) - 0.48 [\ln(I^H/H) - 0.192 \ln(P^H/P^C) + 3r]_{-4} \\ & - 0.003 S - 0.05 S1 - 0.02 S2 \end{aligned}$$

The expression in square brackets gives the long run relationship between housing investment and its explanatory variables.<sup>35</sup>

Note that the condition,  $-1 < \alpha < 1$ , is met in our supply model as well, where  $1 - \alpha = 0.48$ , which implies  $\alpha = 0.52$ .<sup>36</sup> Thus our model met the stability condition. Whenever a supply shock hits the housing sector, error correction will start in direction of steady state. This will continue until the system is back to its equilibrium level.

The solved long run equation (3.19) on the supply side excluding the short run dynamics can be written as:

$$\begin{aligned} \ln(I^H) &= 0.0911036/0.475153 \ln(P^H/P^C) - 1.42673/0.475153 r \\ \ln(I^H) &= 0.2 \ln(P^H/P^C) - 3r \end{aligned} \quad (5.2)$$

where equation (5.2) gives the long run value of housing investment.

The error correction coefficient is negative and significant with a value of -0.48. The interpretation is that when housing investment begins to diverge from its long run equilibrium value Tobin's q error correct it (i.e. 48 % of the error is corrected within one year). E.g. when housing investment is quite low as compared to its equilibrium value, either house price pick up or the construction cost goes down, i.e. Tobin's q will increase. This increase will push housing investment up, and error corrects it towards its long run value.

<sup>35</sup> The expression measures the deviation between the housing investment in the last year and an estimated long run relationship between housing investment, Tobin's q, and the real interest rate.

<sup>36</sup> As the autoregressive (AR) coefficient (coefficient for the long run relationship) is significantly different from zero, this implies that the variables which form the long run relationship are co-integrated in levels.

As the results show, the speed of adjustment is quite fast, which reflects that our model is quite richer than the simple Tobin q model. Since our model gets significant effects from the interest rate as well, which is the cost of financing the investment, the error correction mechanism is faster as compared to simple Tobin's q.

The Tobin's q is also significant in both short and long run. The short run q has an elasticity of 0.32, and the long run q has an elasticity of 0.2. Thus a 1% increase in q will raise housing investment by 0.2% in the long run.

Regarding real interest rate, one percentage point increase in the real interest rate would decrease housing investment almost by 3%. Real interest rate is a significant variable for the supply side in both long and short run, whereas it was a significant variable for demand side only in the long run. Interest rate reflects the cost of borrowing in order to finance housing investment. Since financing cost is one of the costs of constructing housing, so an increase in interest rate would shift the supply curve left, and reduce quantity supplied. The significance of real interest rate in both long and short run show that housing investment or supply side is more sensitive to real interest rate as compared to demand side.

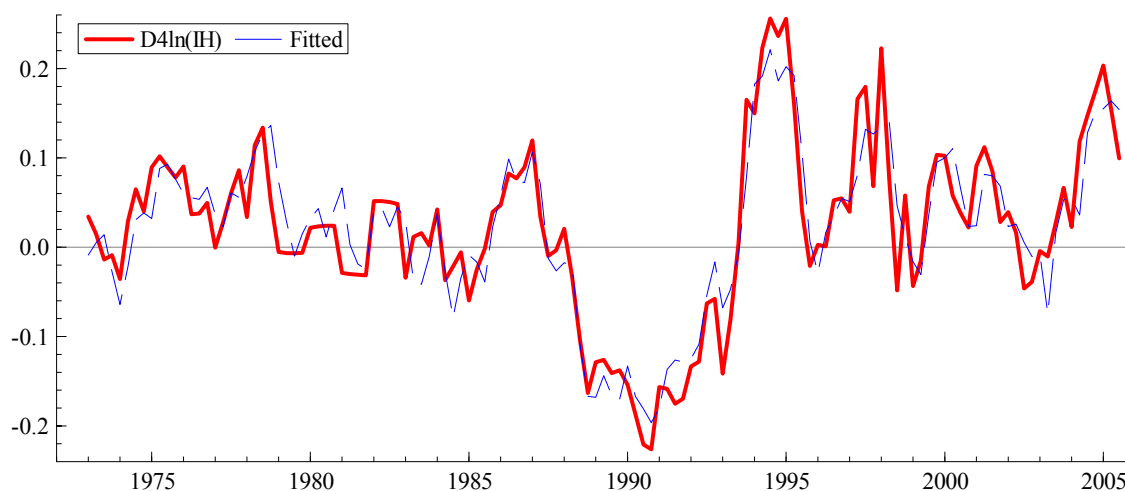
The main feature of housing investment and house prices that make their study a challenging one for econometric methods is their cyclical behaviour, which can be mainly attributed to the construction lags and the resultant sluggish supply<sup>37</sup>. Over the very short run, since the level of housing completion is small relative to the total stock of housing, it is argued that the supply of housing is completely fixed. The extent to which supply is inelastic and sluggish depends on a range of factors including the structure of the construction industry, land availability, regulatory policies etc. Against this, over the medium to long run, building firms in the construction industry will make their production decision based on the expected profitability of house building activity. Over the medium to long run, therefore, the supply of housing is thought to be quite, although not perfectly elastic.

Finally, figure 7 and 8 shows that our model tracks the size and the direction of changes in housing investment exceptionally well.

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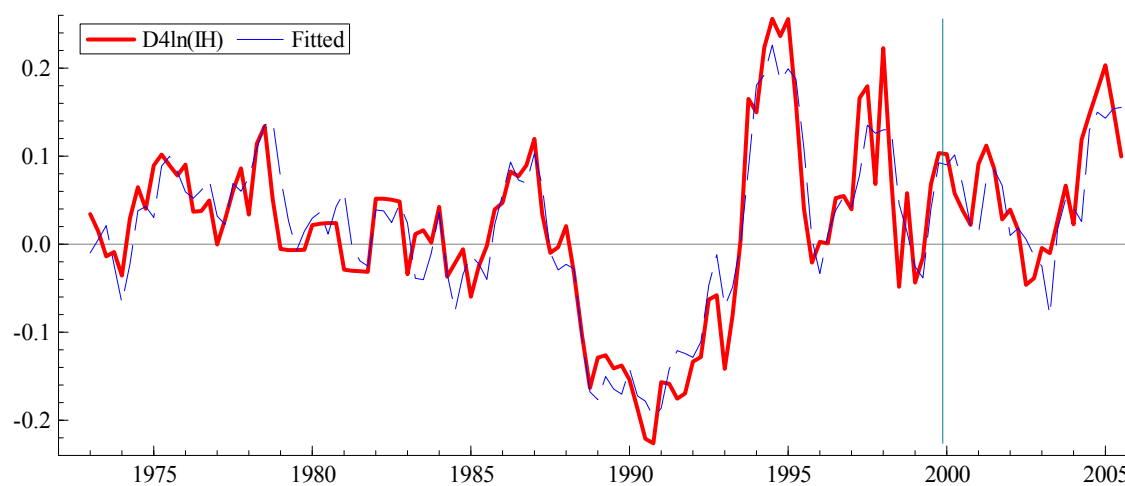
<sup>37</sup> When a positive demand shock occurs, supply adjusts only gradually, mainly due to construction lags. This inflexibility in supply thus generates a cyclical effect on both house prices and quantities supplied.

**Figure 7. Supply side: Within sample forecast**



As the figure shows, the fitted values closely follow the actual ones, implying that our model tracks the change in real house price quite well. However, comparing with demand side, the fit seems not as good as it is for demand side.

**Figure 8. Supply Side: Out of sample 1-step forecast: 2000-2005**



As the figure shows, in the 1-step forecast, the forecasted values closely follow the actual ones, implying that our forecast is reliable.

### 5.2.1 Sub samples and variations of supply model:

Appendix 3b presents results for different models. These include the standard model, model (3b-1), the pure short run models (3b-2)-(3b-3), and sub sample models (3b-4)-(3b-7).<sup>38</sup>

Model (3b-1) is our main model that we are using for analysis of supply side of housing market and for purpose of forecasting. As was the case with demand side, the other models are used to see what change occur in the estimates values and what's the effect on the significance of different variables when the sample includes just the short run dynamics or when the sample size is changed.

In model (3b-2) all variables are significant except annual change in GDP that contribute towards short run dynamics. The model is not acceptable due to serially correlated residuals. However inclusion of the lagged dependent variable in (3b-3) eliminates a considerable part of the serial correlation and lowers the parameter estimates of all the other variables except GDP, which is now significant as well.<sup>39</sup>

It should also be noted that the inclusion of lagged dependent variable causes model's sigma to go down and  $R^2$  to go up. This improvement reflects that additional information is used in model (3b-3), i.e. inclusion of lagged dependent variables.

Model (3b-4) is sub sample for period 1973-1985, and model (3b-5) is sub sample for period 1986-2005. The break point is chosen to be 1985, since credit market deregulation was done around this time. As the results of the two sub regressions show, real interest rate become significant both in the long and short run after deregulation. Thus deregulation makes real interest rate significant. Also after deregulation, most of the variables that contribute toward short run dynamics become insignificant. E.g. housing stock and GDP. The Tobin's q changes its sign after deregulation, i.e. it becomes positive now, which is in accordance with economic theory. However, the sigma of the model (3b-4) is less than that of the model (3b-5).

Model (3b-6) is sub sample for period 1973-1991, and model (3b-7) is sub sample for period 1992-2005. Year 1992 is selected as the break point because tax reforms were applied in

<sup>38</sup> All the models, i.e. model (3b-4) to model (3b-7) starts by including the same variables that were used to get to the results obtained in model (3b-1).

<sup>39</sup> As stated earlier in section 5.1.1, inclusion of lagged values of the dependent variable causes the DW statistic to be biased towards non rejection of the null hypothesis. Hence in such a case DW close to 2 should not be taken as evidence of non rejection of the null hypothesis.

1992. As the results show, after the tax reform, the nominal interest rate becomes significant in the long run along with annual change in GDP. However, both sigma and  $R^2$  of the model (3b-6) suggests that it is a good model as compared to model (3b-7).

### 5.3 Diagnostic and Misspecification tests:<sup>40</sup>

Misspecification tests are concerned with the adequacy of a model as a basis for inference—for example, can the assumption of normality be maintained, are the residuals consistent with innovation errors, are the parameters constant over time<sup>41</sup>? The null hypothesis in this context is usually that some aspect of the model is adequate, the alternative being that it is not. A rejection of the null hypothesis does not usually lead to the conclusion that there is a unique alternative. For example, the DW test for a first order autoregressive disturbance is also able to detect other types of autocorrelation, incorrect functional form and omitted (auto correlated) variables. Hence, rejection of the null hypothesis using the DW test statistic does not automatically imply acceptance of the alternative for which it was originally designed.

We have conducted a summary testing sequence on the residuals for a range of null hypothesis of interest, including: autocorrelation, autoregressive conditional heteroscedasticity (ARCH), the normality of the distribution of the residuals, heteroscedasticity, and functional form miss-specification.<sup>42</sup>

#### **Autocorrelation:**

The residuals for the demand and supply side are plotted in figure 9 and figure 10 which extend the idea behind the DW test to plot the correlations between successive lagged residuals. A random residual would have most such correlations close to zero. Visually, the dependence between successive residuals is small, which seems to suggest that there is no autocorrelation between the residuals. Whether or not there is a pattern can be assessed formally by the serial correlation test statistics; one of which is value of DW. Since DW statistic is not significant for both demand and supply side, it suggests that there is no serial

<sup>40</sup> See Patterson (2000), pages 169-185 and also Hendry and Doornik (2001), page 56.

<sup>41</sup> To check parameter constancy, I have performed recursive estimation, 1-step chow test, 1-step residual test and break point chow test on both demand and supply side parameters. See appendix 4.

<sup>42</sup> The results for these tests are given in appendix 3a, model (3a-1) and appendix 3b, model (3b-1) for demand and supply sides respectively.

correlation between the residuals.<sup>43</sup> Also the AR test (error auto-correlation test) for both the demand and supply side don't give any evidence of auto correlation.

### **Heteroscedasticity:**

The results for the diagnostic test ARCH (autoregressive conditional heteroscedasticity test) and hetero test (heteroscedasticity test using squares) are significant at 1% level suggesting heteroscedasticity on the demand side. However the hetero X test (heteroscedasticity test using squares and cross products) reject the hypothesis of heteroscedasticity, suggesting that although there is some heteroscedasticity present in the model, but it's not pronounced. On the supply side, the diagnostic test for heteroscedasticity rejects the hypothesis of heteroscedasticity.

### **Normality:**

Hypothesis testing requires specification of the distribution of a test statistic under the null hypothesis. In regression analysis the test statistic often depends upon the disturbances, which are usually assumed to be normally distributed. Alternatively, even if the disturbances are not normally distributed some weaker assumptions, for example that they are independent and identically distributed, are sufficient for the normality of the OLS estimators to hold asymptotically. Hence, it is important to note that if the test indicates non-normality, then a typical response is not that another distribution should be specified, but rather that there are outlying residuals suggesting that the regression model is miss-specified.

The diagnostic test for both the demand and supply side suggests normality of the regression disturbances. This is also evident from figure 9b and 10b, where the distribution of residuals is almost similar to a normal distribution.

### **Functional form RESET test:**

Regarding the functional form of the regression model, economic theory usually doesn't say much about the precise functional form of the relationship among the variables of interest. In this regard, linearity often seems to be the simplest practical choice, since all linearity requires is that there is a linear relationship among some transformation of the variables. For example,

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<sup>43</sup> However, since our model include lagged values of the dependent variable, the DW statistic is biased towards non rejection of the null hypothesis, hence in such a case DW close to 2 should not be taken as evidence of non rejection of the null hypothesis.

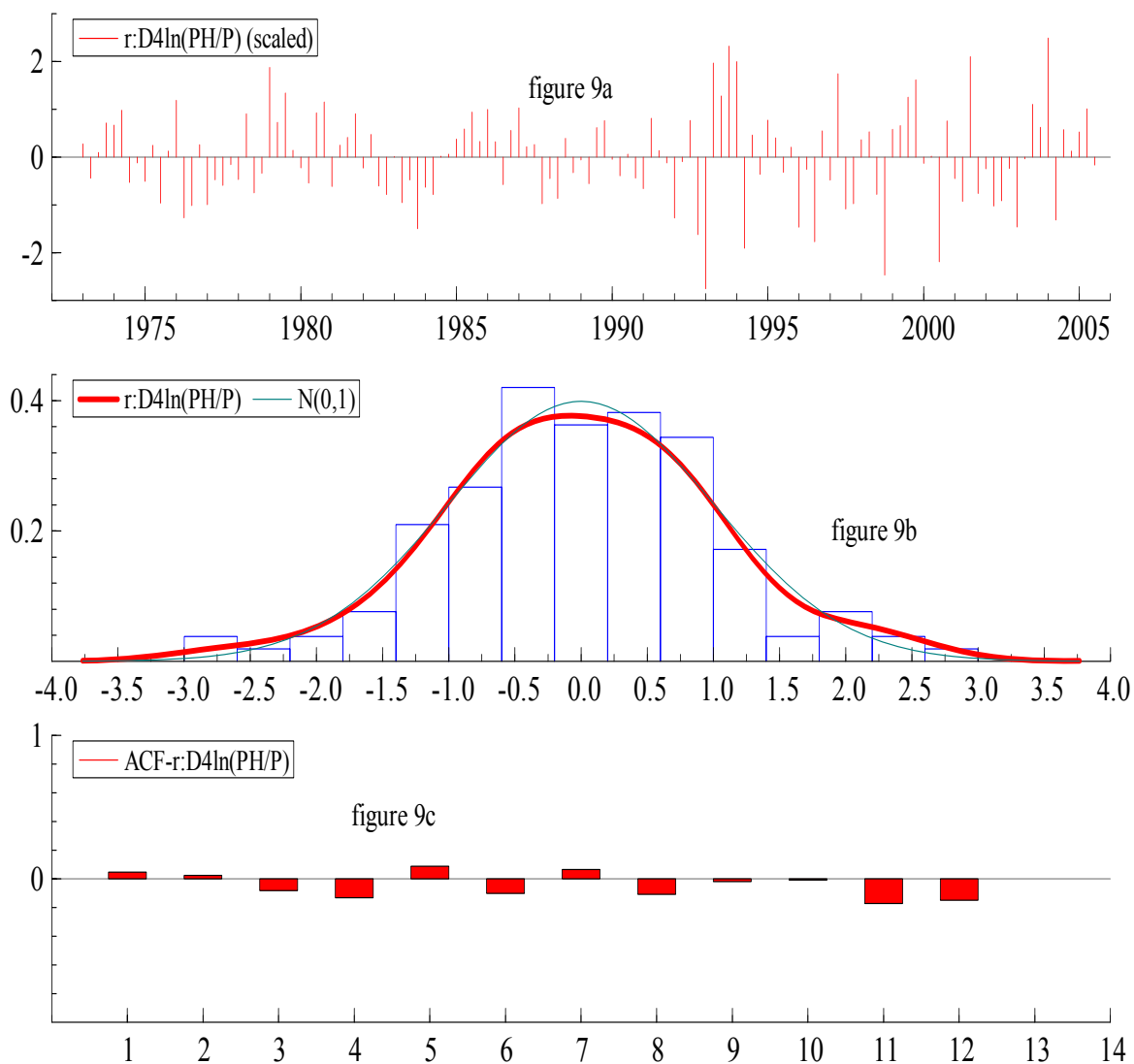
our model is multiplicative in the levels but linear in the logarithms. In order to test the functional form, RESET test is used. This test first adds the squared fitted values of dependent variable to the linear regression and test for the significance of this additional variable. Hence the RESET test is an indirect way of testing whether the square of the regressor is significant.

The diagnostic test for both the demand and supply side pass the RESET test, which implies that our functional form is correct.

In short, with respect to residual diagnostics, the supply side clears the entire residual based test. Whereas the diagnostic test for the demand side show that the ARCH test is significant at 1% level.

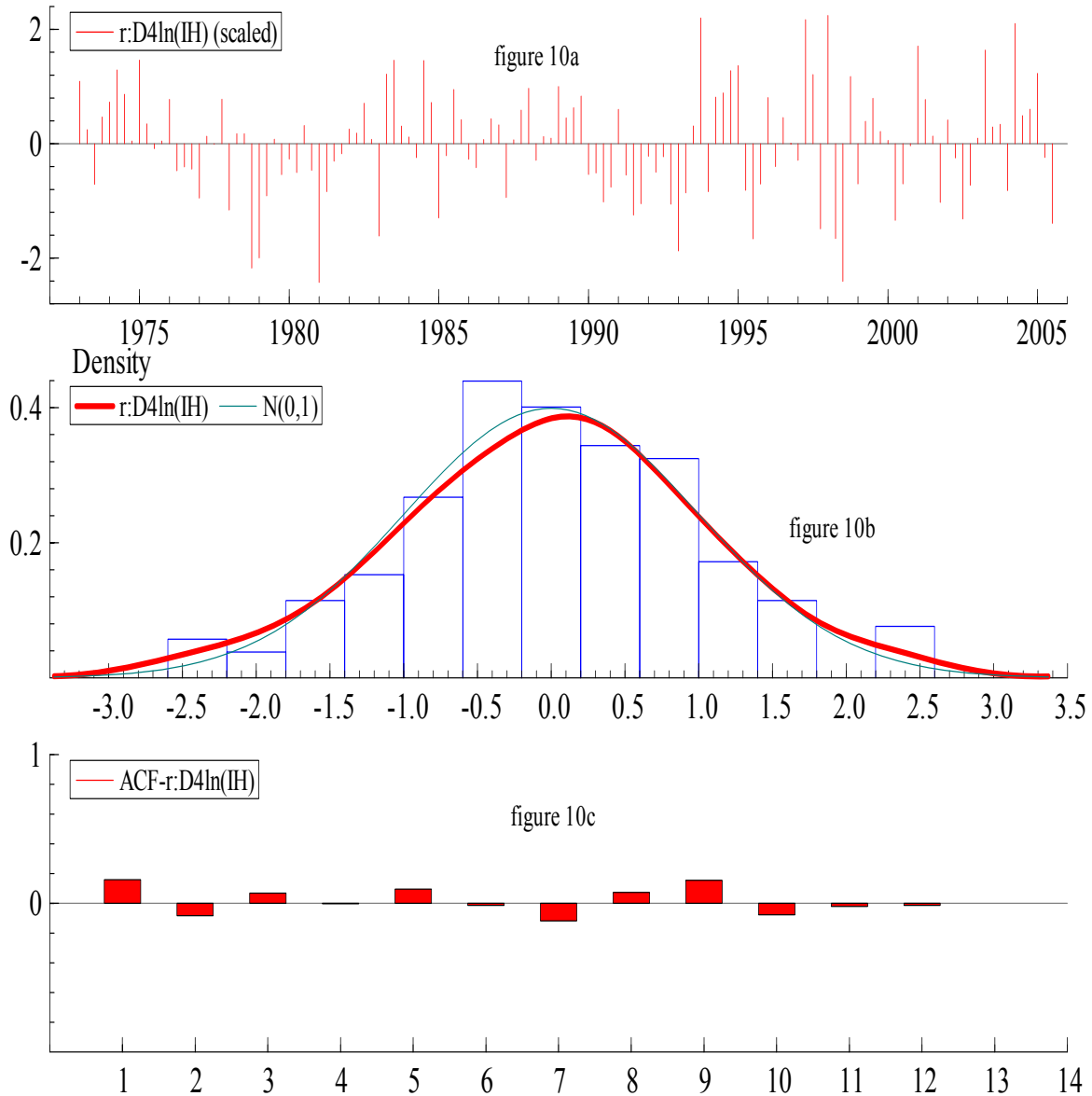


**Figure 9: Residuals plotted for demand side\***



\*Figure 9a show the scaled residuals which don't seem to be correlated as such. Figure 9b depict that the residuals almost have normal distribution. Figure 9c gives the corelogram for the residuals which show that there is no serial correlation present between the residuals.

**Figure 10: Residuals plotted for supply side\***



\*Figure 10a show the scaled residuals which although don't seem to be correlated as such but show a pattern as compared to demand side residuals. Figure 10b depicts that the residuals almost have a normal distribution, however the mean of the residuals distribution is not zero, as it was for demand side. Figure 10c gives the correlogram for the residuals which shows that there is no serial correlation present between the residuals.

## 6. Forecasting

The secondary objective of the paper was to investigate if changes in house prices can be predicted. According to Meen (2001), the UK national housing models for owner occupied homes have broken due to the structural changes after 1990 which has resulted into that the parameters of house price equations have been particularly volatile compared with other aggregate time series relationships. Since structural changes have taken place in Norway as well, thus it is important to know whether house prices can be predicted or not using the stock flow model.

To perform this task, we evaluate our model from a forecasting point of view. The quality of the model is analyzed by its ability to produce ex ante forecasts. In order to do this in a realistic manner, we perform ex-ante (out of sample) forecasts for the period 2000-2005 using data for 1973-1999, and see how good is the forecast for the period 2000-2005.

Along with using our model, we forecast using a naïve autoregressive (AR) process, so we are able to compare our model results with another model. The AR process that we use is a random walk model, i.e. the coefficient of the lagged auto-regressive term is taken to be 1. The idea of a random walk is an important one in several areas of economics, especially where the concept of fully efficient markets rules out the possibility of profitable speculation on the course of, for example, the prices of financial assets or housing. Therefore we will judge the accuracy of our model by comparing its results with that of a random walk model. The random walk model implies that the best guess of a time series  $Y_{T+1}$ , given information at time  $T$ , is  $Y_T$ , this is because there is no predictive structure in the AR process or the  $\varepsilon_t$  (residuals) process as the latter has, by assumption, zero mean, constant variance and zero autocorrelations at all lags.<sup>44</sup> The random walk model is therefore taken as a baseline model for financial markets and for housing market as well. I.e. it's not possible to exploit the past history of house prices to systematically make profits by speculating on the future course of the housing market.

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<sup>44</sup> See Patterson (2000), pp 209.

The naïve AR models have been estimated with the following specifications for the demand and the supply side respectively:

$$D^4 \ln (P^H/P) = f(D^4 \ln (P^H/P)_{-1}, D^4 \ln (P^H/P)_{-2})$$

$$D^4 \ln (I^H) = g(D^4 \ln (I^H)_{-1}, D^4 \ln (I^H)_{-2})$$

Where,  $f$  and  $g$  are linear in their arguments.  $D^4 \ln (P^H/P)$  is the annual change in real house prices, and  $D^4 \ln (I^H)$  is annual change in housing investment.

There are several commonly used measures of forecasting accuracy: the root mean square error (RMSE), mean absolute error (MAE), the mean absolute proportional error (MAPE) and the mean percentage error (MPE).

We will use RMSE in order to evaluate the forecast accuracy of the two models.<sup>45</sup>

Where,

$$RMSE = [1/H \sum_{t=1}^H (Y_t - f_t)^2]^{1/2}$$

$H$  = forecast horizon (23 in our case),  $Y_t$  the actual values, and  $f_t$  the forecasts.

Also we use dynamic forecasting rather than the static 1-step ex-post forecast, since the former is more meaningful as it use all the past values of dependent and explanatory variables in order to make forecast, whereas the latter uses just the one period prior value of the dependent variable, hence the name 1-step forecast. The 1-step forecast was presented in figure 6 for demand side, and in figure 8 for supply side.

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<sup>45</sup> See Hendry and Doornik (2001), pp 62-64

Results on the out of sample forecasting accuracy are presented below.

**Forecasting accuracy housing prices, Demand Side (2000-2005)**

Measures	AR naïve model	Actual model
RMSE %	0.054	0.035
$R^2$	0.915	0.962

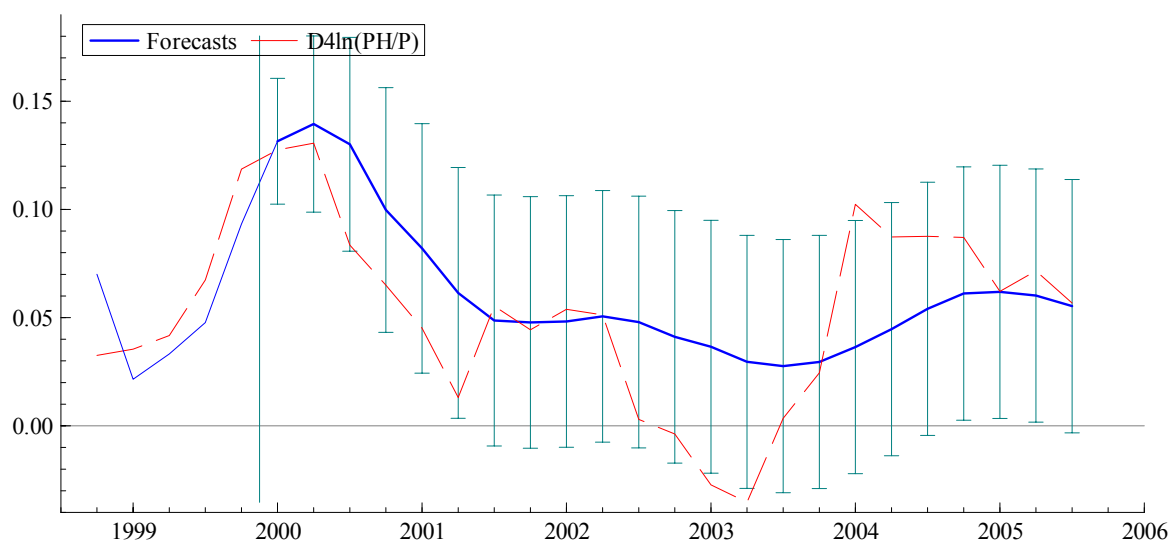
**Forecasting accuracy housing investment, Supply Side (2000-2005)**

Measures	AR naïve model	Actual model
RMSE %	0.077	0.047
$R^2$	0.729	0.856

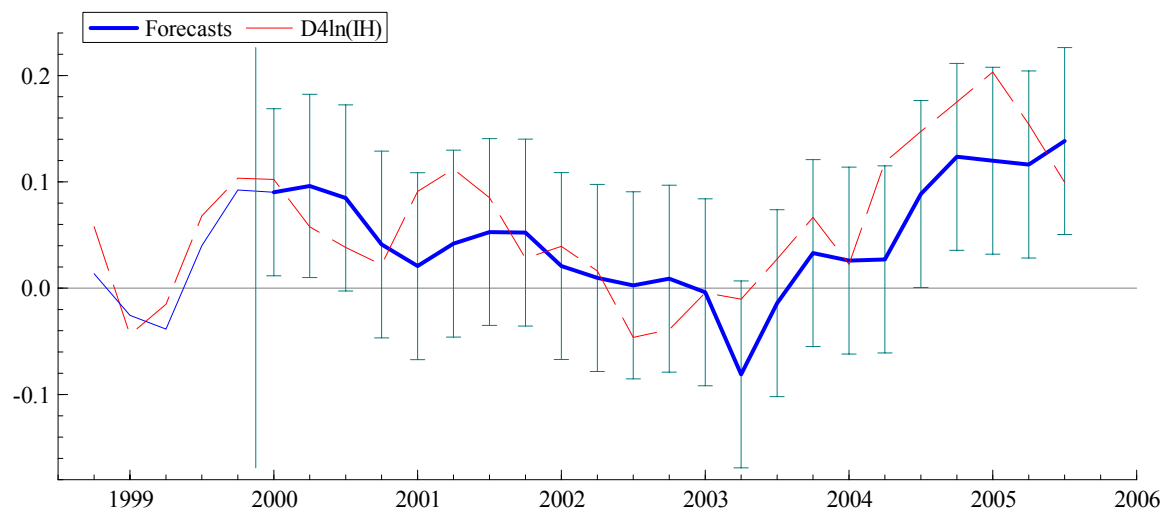
Based on the value of RMSE, we conclude that the structural model's forecasting accuracy is better than its naïve AR counterpart. Thus we can't say that house prices follow random walk just like financial assets. There are many other factors that together determine the course of house prices along with the lagged values of house price itself.

Figure 11a and figure 11b show the dynamic forecast for demand and supply side for the structural model. Figure 12a and figure 12b show the same for random walk model. Both figures support the conclusion that structural model forecast better than the naïve model.

**Figure 11a**  
**Demand side: structural model**

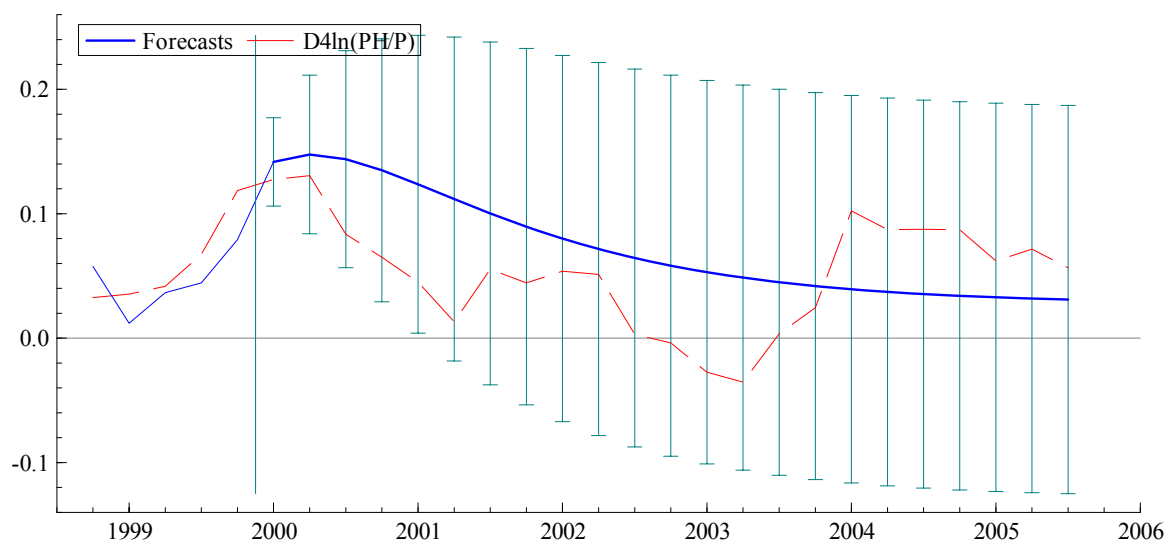


**Figure 11b: Supply side**  
**Structural model**

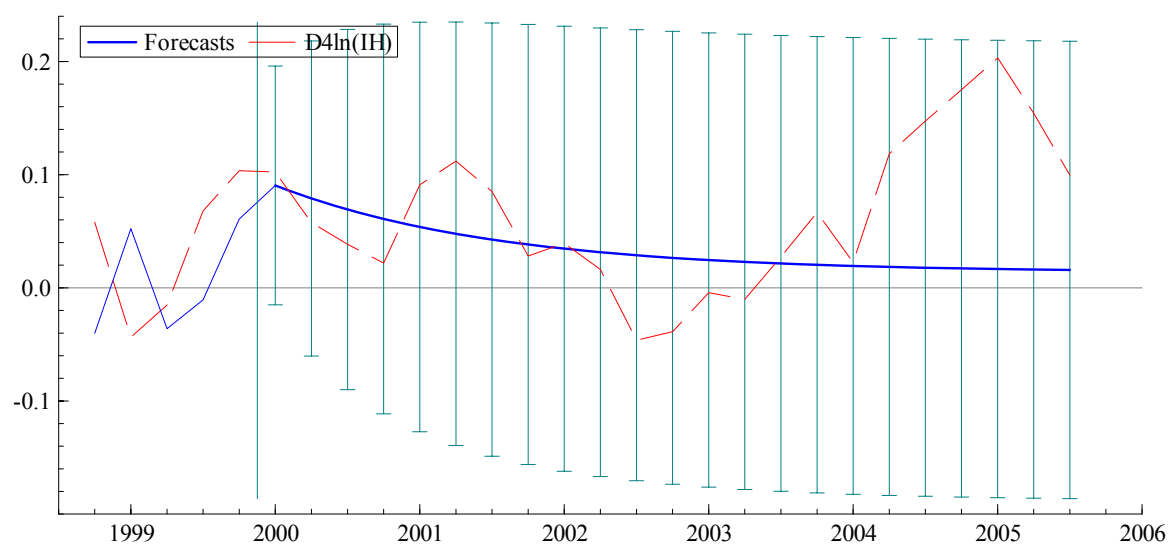


In both cases, the forecasted values are not only within the 95% confidence interval but also is the interval quite narrow, which implies that our model can be used to forecast the values for house prices and housing investment. i.e. there is 95% probability that our forecast will be correct and within the confidence interval.

**Figure 12a**  
**Demand side: random walk model**



**Figure 12b**  
**Supply side: random walk model**



As both the figures show, the 95% confidence interval is much wider here as compared to that in figure 11. This implies that the naïve AR model is not a good one to forecast values for house prices and housing investment.

## 7. Conclusion

The house price model presented in the paper has the necessary features of a valid model, i.e. the model is data consistent, incorporates lags, has a plausible long run solution and includes a full range of explanatory variables. Our model captures long run fundamentals such as the effect of income, the housing stock and interest rates on the long run real house prices. It also builds in the effect of house price dynamics. We also allowed for the structural breaks in our model, like the credit market deregulation and tax reforms. The credit market deregulation has a direct effect on the level of real house price (as our final regression on demand side show, given as model (3a-1), appendix 3a).

The results from the ADF test indicates that all the variables have unit root i.e. they are integrated of order 1. Since all the variables are co-integrated in levels, on both demand and supply side, this indicates two co-integrating relationships, representing the demand and supply side.

The results on the demand side indicate that the change in debt has a strong effect in short run dynamics whereas it is insignificant in long run. One of the reasons for this insignificance can be the positive relationship between debt and income. Since income is the first security against debt servicing problems, people with higher income levels get loans easier as compared to the others. As we got real disposable income corrected for dividends significant in the long run, this might be the reason for the insignificance of debt in long run. The positive relation between the two can make one of the variables appear to be insignificant. According to Norges Bank (2005), average debt in the group of “indebted households” rose by 95% from 1987 to 2003. In the same period, this group’s average disposable income increased by 100% and average financial assets by 122%. Even if we exclude dividends from the average disposable income, the growth in income is quite high and gives a positive development in the relation between income and debt.

Another reason for the insignificance of debt can be the fact that mortgage debt is more sensitive to house prices than total household debt, which includes debt incurred also in order to buy other durables.



Gross financial wealth is used instead of net because in this way we not only get to know the effect of the financial assets and liabilities of the households in the estimated regression, but also get two different coefficients for the respective components (net worth and indebtedness) when it is decomposed. Net financial wealth is important when buying a house, as it reduces the amount of money that the household needs to loan out. Usually an increase in debt is considered to be an indicator of consumer optimism and strong demand. In Norway, almost everyone buy house with debt financing, which tells us that real house prices and debt could be positively correlated. As people get more debt, they buy more houses, which increase house prices.

But we should be aware of the fact that an increase in indebtedness or a drop in holdings of financial assets would raise the risk of bankruptcy. This fear of bankruptcy would force the consumer to shift his demand from housing and durables to consumption of non durables, which don't require use of financial wealth. This shift in demand from housing to non durables will decrease house prices. Thus, high debt can lead to lower house prices.

This kind of behaviour can be one of the reasons why we don't get debt as a significant variable in long run in our final regression. I.e. on one hand, high debt implies high housing demand, and on the other hand, high debt implies low demand for houses, thus the two effects cancel each other in the long run, and debt appears to be insignificant.

Real interest rate matters for both house prices and housing investment. Increase in real interest rates reduces consumption demand for housing through intertemporal substitution and reduce investment demand because return on alternative assets rises. As the regression results show, interest rate is highly significant for housing demand in Norway. The particular interest sensitivity of housing demand seems to stem partly from frictions in capital markets. Since these can change over time, it is also likely that the interest sensitivity and cyclicity of housing investment can vary through time as well.

Related to the frictions in the capital market argument, one reason for the interest sensitivity of housing demand can be the variable rate of mortgage in financial market. As emphasised by MacLennan et al (1998) in the European context, the structure of the mortgage finance industry largely determines the speed of transmission of changes in interest rates to mortgage borrowing behaviour. Australia and UK, where mortgages are offered at variable rates,

display more overall interest sensitivity than does US, where institutional arrangements are designed to support the existence of a long term fixed rate mortgagee market. The case of Norway can be characterised similar to UK, as rates are variable here as well.

The ECM adjustment coefficient for the level of real house prices indicates that in case of departure from equilibrium, 7% of the shock is corrected within one year. However it must be pointed out that in ECM, owners of occupied homes are allowed to make mistakes in the short run which will be corrected in the long run.

Regarding the supply side, we find that Tobin's  $q$  is significant both in short run and long run. The data fits the Tobin's  $q$  model quite well. The out of sample forecast is quite accurate for the supply side. The model is richer as it includes the interest rate reflecting the cost of financing housing investment. The speed of adjustment is 44%, which is quite high. The forecasting evaluation indicates that the model is more accurate than its naïve autoregressive counterpart with respect to RMSE.

Talking about fit of the model, we got a relative poorer fit for the supply side as compared to the demand side. One possible reason for this can be the inclusion of GDP mainland in the supply equation. GDP mainland for Norway is quite a fluctuating variable. A good rainy season will be a blessing for the hydro power sector, which then lead to a higher GDP. But this increase in GDP due to a good performance by hydro sector has no relation with housing market. Thus using GDP as an explanatory variable may not help to explain variation in housing investment. An alternative could be to use investment in all other sectors, except housing sector, as an explanatory variable for housing investment.

Although the housing sector is generally considered to be more sensitive and volatile than the economy as a whole, the degree of this sensitivity seems to vary between countries and through time. As we see in case of Norway the house prices were low before credit market deregulation. After deregulation and lowering of interest rate, housing market has experienced a boom in Norway. Brunnermeier and Juilliard (2006) attribute the rising house prices in UK and USA to the money illusion. According to them, falling inflation and nominal interest rates (holding real interest rates fixed) leads people to wrongly attribute a decrease in nominal interest rate to a decrease in the real interest rate and consequently underestimate the real cost of future mortgage payments. This underestimation in turn increases housing demand and

hence put pressure on house prices. This argument seems to be quite applicable to Norway, as both nominal interest rate and inflation has been quite low in Norway since the last few years. Thus, the results are not only model-dependent but also depend on what is happening in the economy and how the policies are being formulated.

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## Appendix 1: Data description

The data used in the estimation is quarterly and it covers the period of 1973-2005.\* Using quarterly data is better than using annual data; since quarterly data provide us with larger number of observations and this in turn give us larger number of degree of freedom to perform different types of tests and to draw inferences.

The housing demand side is explained by a number of explanatory variables including: Real house price, real disposable income minus dividends, total population, real interest rate, employment rate, household debt, consumer price index, housing stock to income ratio, financial wealth to income ratio, debt to income ratio and dummies for tax reforms and credit market deregulation.

The supply side is explained by housing investment, ratio of house price to construction price, GDP, and housing stock.

The variables are given below:

H: Housing capital (stock)

$I^H$ : Investments in houses

$P^H$ : Nominal house prices

CPI: Consumer price index

D: Households value of gross debt

$P^C$ : Investment price for house capital (approx: cost of building houses)

(NB: does not include cost of land)

Y: Disposal income

GDP: GDP Mainland

$Y^D$ : Disposable income minus dividends

POP: Population (in 1000)

E: Employment rate

TRTMNW: Tax rate on capital gain

VKI300: Households value of real capital except houses

BF300: Households value of gross claims

$W^F$ :  $VKI300 + BF300$  = gross financial wealth

RENPF300: Average interest rate of dept for household

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\* see KVARTS Databank, Statistics Norway

## Appendix 2: Unit root test

Table A2: Augmented Dickey Fuller Test Results (ADF test)\*

Variable	with constant	with constant & trend	Conclusion
ln (PH/P)	-0.7426 (1)	-1.003 (1)	I (1)
ln (Yd)	-8.315** (3)	-3.182 (3)	I(1)
ln (POP)	1.995 (1)	-1.087 (1)	I (1)
ln (E)	-1.863 (4)	-2.434 (4)	I (1)
ln (D)	-1.243 (2)	-2.100 (2)	I (1)
ln (H)	-1.776 (1)	-2.256 (1)	I (1)
ln (WF)	-5.575** (3)	-1.464 (3)	I(1)
ln (IH)	0.02219 (2)	-0.2558 (2)	I (1)
ln (PH/PC)	-1.953 (4)	-2.628 (4)	I (1)
ln (P)	-3.314* (4)	-1.386 (4)	I(1)
r	-1.694 (3)	-1.863 (3)	I (1)

Critical value 5%	-2.88	-3.44
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\* A constant, a linear and a quadratic trend can be included while conducting the integration test. The constant (intercept) reflects the possibility that under the alternative of stationarity, the intercept is not zero. Introducing a trend into the equation allow the alternative to be trend-stationary. Maximum number of lags is chosen to be 1 to 4, which pre-whiten the residuals. We had to give longer lags for more persistent variables like employment, Tobin's q and CPI. However the result stays the same.

For GDP, financial wealth and CPI, we rely on results using both constant and trend, since these variables do exhibit a trend or grow over time. For interest rate, we rely on result using only constant, since interest rate does not show trend like growth over time.

The test has been carried out in PCGIVE, see Hendry and Doornik (2001)

The values in brackets show the number of lags to use.



## Appendix 3a: Demand Side

**Model (3a-1): The demand side results (1973-2005)  $D^4\ln(P^H/P) =$**

<b>Regressors</b>	<b>Coefficient</b>	<b>T-Statistics</b>
Constant	-1.28981	-5.54
<b>Short Run</b>		
$D^4\ln(P^H/P)_{-1}$	0.944809	19.6
$D^4\ln(P^H/P)_{-4}$	-0.562667	-6.89
$D^4\ln(P^H/P)_{-5}$	0.385549	5.47
$D^4\ln(D)$	0.273869	4.82
<b>Long Run</b>		
$\ln(P^H/P)_{-4}$	-0.118011	-6.65
$\ln(H)_{-4}$	-0.0397208	-1.48
$r_{-4}$	-0.396663	-2.74
$\ln(Yd/P)_{-4}$	0.152234	5.08
DREG	-0.0113493	-1.72
Seasonal	0.0151804	3.17
Seasonal_1	0.00293657	0.69
Seasonal_2	-0.00208888	-0.539

$R^2$	0.956
Std Err	0.0152
D.W	1.9

<b>Diagnostics:</b>		
AR 1-5 test:	F (5,113) =	1.2837 [0.2759]
ARCH 1-4 test:	F (4,110) =	3.6777 [0.0075] **
Normality test:	Chi^2(2) =	1.7008 [0.4272]
Hetero test:	F (20, 97) =	2.1195 [0.0082] **
Hetero-X test:	F (83, 34) =	1.1289 [0.3538]
RESET test:	F (1,117) =	2.2393 [0.1372]

<b>model (3a-2):</b> 1973 (1) to 2005 (3)	<b>model (3a-3):</b> 1973 (1) to 2005 (3)
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	Coefficient	T value	Coefficient	T value
D4ln(E)	5.27	7.3	0.94	3.24
D4r	0.37	0.75	0.49	2.86
D4ln(P)	-0.49	-2.91	-0.04	-0.638
D4ln(D)	0.62	5.88	0.02	0.373
D4ln(POP)_5	14.87	4.21	1.75	1.32
D4ln(PH/P)_1			1.12	25.8
D4ln(PH/P)_4			-0.66	-7.26
D4ln(PH/P)_5			0.43	5.49

Sigma	0.0502349	Sigma	0.0173445
R^2	0.500463	R^2	0.941915

<b>model (3a-4):</b> 1973 (1) to 1985 (4)	<b>model (3a-5):</b> 1986 (1) to 2005 (3)
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	Coefficient	t-value	Coefficient	t-value
D4ln(PH/P)_1	0.82	13.8	0.81	11.3
D4ln(PH/P)_4	-0.12	-2.83	-0.53	-5.29
D4ln(PH/P)_5			0.35	4.01
r_4	-0.69	-3.59	-0.45	-2.19
i_4	-8.44	-6.13		
D4ln(P)	-0.23	-3.89		
D4ln(D)			0.37	2.89
lnH_4	0.16	2.49	-0.25	-1.34
lnWF_4	0.05	2.25		
ln(PH/P)_4	-0.07	-2.16	-0.15	-4.42
ln(Yd/P)_4			0.32	3.11

Sigma	0.00899114	sigma	0.0169375
R^2	0.973784	R^2	0.960937

<b>model (3a-6):</b> 1973 (1) to 1991 (4)	<b>model (3a-7):</b> 1992 (1) to 2005 (3)
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	Coefficient	t-value	Coefficient	t-value
D4ln(PH/P)_1	1.07	19.0	0.56	8.04
D4ln(PH/P)_4	-0.57	-4.74		
D4ln(PH/P)_5	0.32	2.95	0.285157	3.17
D4ln(D)	0.17	3.97	1.46419	4.58
ln(PH/P)_4	-0.06	-2.35	-0.856783	-6.97
D4ln(POP)_5	-3.43	-2.79		
D4r	0.4	3.36		
lnH_4			-3.83661	-2.68
ln(D)_4			1.21362	3.47
r_4			-0.626971	-2.34
i_4	-0.73	1.72	3.01602	2.73
D4ln(P)			-0.724537	-2.17
ln(E)_4			2.56835	3.17
lnYd/P_4			0.612367	3.05

Sigma	0.00966759	sigma	0.0163378
R^2	0.984366	R^2	0.935756

## Appendix 3b: Supply Side

**Model (3b-1): The supply side results (1973-2005)  $D^4\ln(I^H) =$**

<b>Regressors</b>	<b>Coefficients</b>	<b>T-Statistics</b>
Constant	-2.28056	-6.49
<b>Short run</b>		
$D^4\ln(I^H)_{-1}$	0.464184	7.98
$D^4\ln(P^H/PC)$	0.316000	4.04
$D^4\ln(H)$	9.11515	5.96
$D4r$	-1.38848	-3.25
$D4\ln(GDP)$	0.139893	1.66
<b>Long Run</b>		
$\ln(I^H/H)_{-4}$	-0.475153	-6.54
$\ln(P^H/PC)_{-4}$	0.0911036	3.96
$r_{-4}$	-1.42673	-3.29
Seasonal	-0.00324971	-0.249
Seasonal_1	-0.0486084	-3.86
Seasonal_2	-0.0199514	-1.94

$R^2$	0.849095
Std Err	0.0392433
D.W	1.66

<b>Diagnostics</b>		
AR 1-5 test:	F (5,114) =	1.8438 [0.1099]
ARCH 1-4 test:	F (4,111) =	1.0840 [0.3680]
Normality test:	Chi <sup>2</sup> (2) =	0.32550 [0.8498]
Hetero test:	F (19, 99) =	1.2296 [0.2501]
Hetero-X test:	F (71, 47) =	1.1341 [0.3260]
RESET test:	F (1,118) =	0.11411 [0.7361]

<b>Model (3b-2):</b> 1973 (1) to 2005 (3)	<b>Model (3b-3):</b> 1973 (1) to 2005 (3)
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	Coefficient	t-value	Coefficient	t-value
D4ln(PH/PC)	0.587663	6.09	0.397456	4.71
D4ln(GDP)	0.0993423	0.885	0.213607	2.31
D4lnH_1	24.2650	8.73		
D4lnH_4	-42.1468	-4.72		
D4lnH_5	18.4181	2.70		
D4i	-4.36675	-2.18	-3.03757	-2.06
D4r	-0.883596	-1.75	-0.593747	-1.41
D4ln(IH)_1			0.771351	12.6
D4ln(IH)_4			-0.244389	-2.73
D4ln(IH)_5			0.177448	2.22

Sigma	0.0521799	Sigma	0.0435079
R^2	0.724237	R^2	0.808281

<b>Model (3b-4):</b> 1973 (1) to 1985 (4)	<b>Model (3b-5):</b> 1986 (1) to 2005 (3)
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	Coefficient	t-value	Coefficient	t-value
D4ln(IH)_1	0.384400	3.30	0.442200	5.82
D4ln(IH)_4	-0.316491	-2.95		
D4ln(PH/PC)	0.147888	1.76	0.513995	4.49
D4ln(GDP)	0.129826	1.98		
ln(IH/H)_4	-0.253817	-2.22	-0.613700	-4.98
ln(PH/PC)_4	-0.0487553	-1.81	0.158410	2.82
D4lnH	5.11256	2.39		
D4lnH_1			11.5952	4.16
r_4			-1.50006	-2.12
D4r			-1.54599	-2.35

Sigma	0.026817	Sigma	0.0446019
R^2	0.698043	R^2	0.87878

<b>model (3b-6):</b> 1973 (1) to 1991 (4)	<b>model (3b-7):</b> 1992 (1) to 2005 (3)
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	Coefficient	t-value	Coefficient	t-value
D4ln(IH)_1			0.193795	1.56
D4ln(IH)_4	-0.207575	-2.07	0.567304	2.10
D4ln(PH/PC)	0.194842	2.44	0.879649	4.76
D4ln(GDP)			0.599118	2.14
D4lnH_4	-13.8158	-5.65	-60.4441 52.4186	-2.08
D4lnH_5			-0.558074	1.86
ln(IH/H)_4	-0.147213	-1.37	0.779294	-3.34
ln(PH/PC)_4	0.0564546	2.37		4.72
D4r	-0.937022	-2.27		
D4lnH	20.3354	10.7	-6.17557	
i_4				-2.60

sigma	0.0315779	sigma	0.0420745
R^2	0.880322	R^2	0.858264



## Appendix 4: Recursive estimation

In order to know whether our parameters estimated for the whole sample 1973-2005 are constant, we perform recursive estimation.\*

The logic of recursive estimation is simply to fit the model to an initial sample of N points and then fit the equation to samples of N+1, N+2 ... up to T observations. The main output will be graphs of coefficients over the sample. This is a powerful way to study parameter constancy.

We set the number of observations for initialization to 18 (i.e. N=18) and also keep 23 observations for forecasting.

### Demand side:

From figure A4.1, we can see that the graph of coefficients of  $\ln(P^H/P)_{-4}$  over the sample shows that around 1990, the coefficient lies outside of the previous confidence interval. Other coefficient that is also non constant around the same period is  $D^4 \ln(D)$ .  $\ln(P^H/P)_{-4}$  give negative estimated value using the whole sample until 2005. However it will give a positive estimation between 1982 and 1984. Similarly  $D^4 \ln D$  give positive value with whole sample, whereas it will give a negative value if we use data up to 1982.

However, the 1-step residuals and the 1-step chow test show outliers around 1994. The 1-step residuals are plotted with  $\pm 2\sigma_t$  ( $\pm 2$  standard deviation) shown on either side of zero. Thus error terms (residuals) which are outside of the error bars are outliers.

A further summary graph is the break point chow test graph. Chow test is a test that the regression coefficients are constant across two mutually exclusive regimes of T1 and T2 observations, conditional on equality of the variances, i.e.  $\sigma_1^2 = \sigma_2^2$ .

We assume no serial correlation in the residuals and the normality of the residuals so that the only problem is that the regression coefficients may not be constant. Ideally, the break point, T1, for the chow test should be informed by some potential source of structural change. We

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\* See Hendry and Doornik (2001), pages 65-67

have identified two possible sources of structural break. One can be the credit market deregulation that occurred around 1986, and the other possible source can be the tax reforms of 1992. Figure A4.3 show the break point chow test for the demand side.

It is difficult to identify the break point exactly because our model uses variables in lags and they are differenced. The break point chow test also show some kind of structural break occurring around the period of 1994, as shown in figure A4.3. This break can be traced back to the change in price level around the same period. However we can't identify the exact break point and its reason because of the structure of our model.

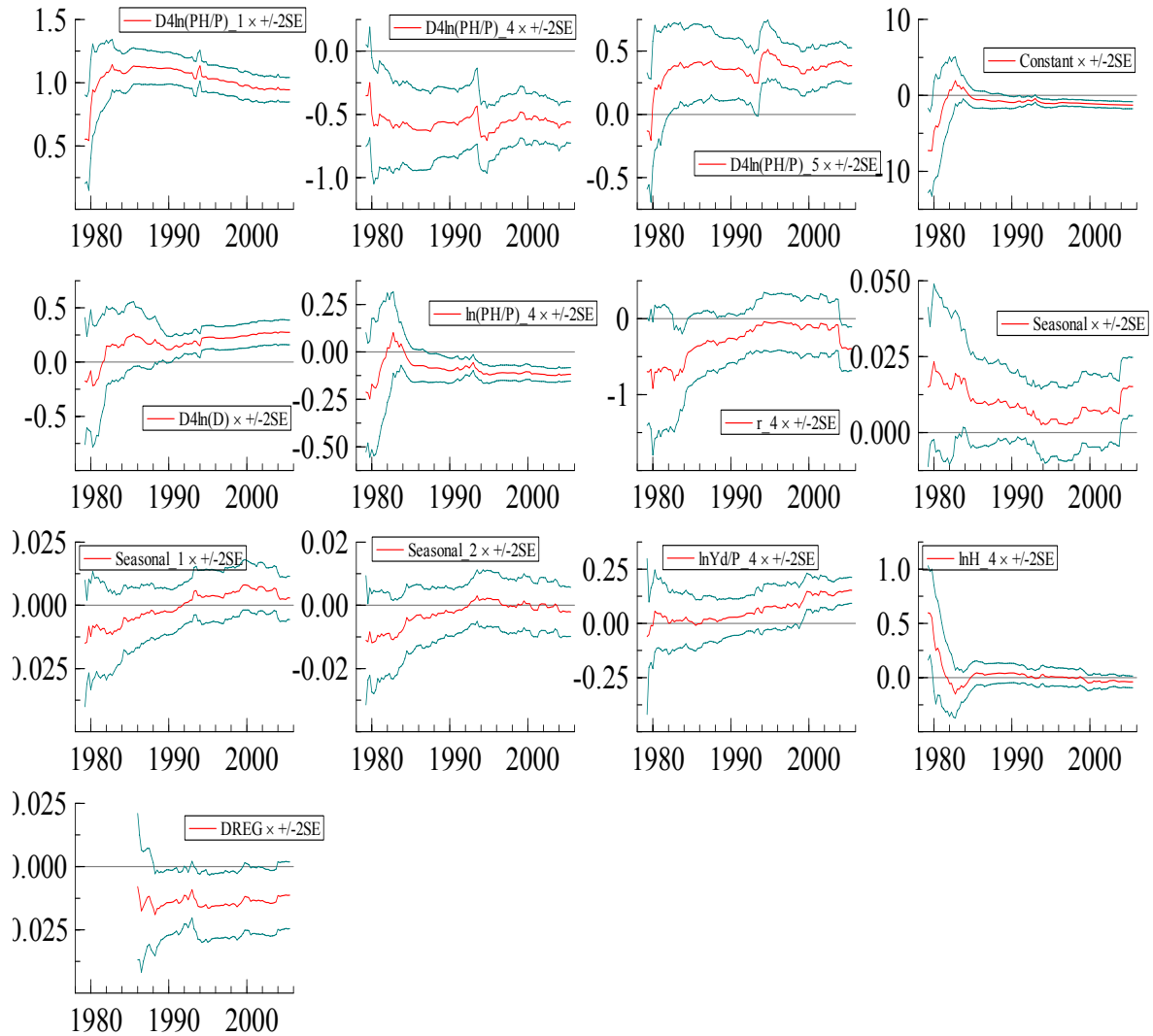
### **Supply side:**

Regarding the behaviour of supply side using recursive graphics, there are more variables that show non constancy as compared to demand side. However, the change of confidence interval is occurring around the same period in both demand and supply side. Variables that lie outside the previous confidence interval around 1990 includes:  $\ln(P^H/P^C)_{-4}$ ,  $r_{-4}$  and  $D^4r$ . Most of the variables change their signs when estimation period is changed. E.g.  $\ln(P^H/P^C)_{-4}$  gives positive value if estimated using the whole sample until 2005. However, as the figure shows, if estimated around 1980 it will give a negative estimate. Similarly  $r_{-4}$  show positive estimation around 1980 and negative around 2005.

The break point as shown by 1 step chow test, 1 step residuals and break point chow test is very similar to that of demand side. The break on supply side also seems to be occurring around 1994.

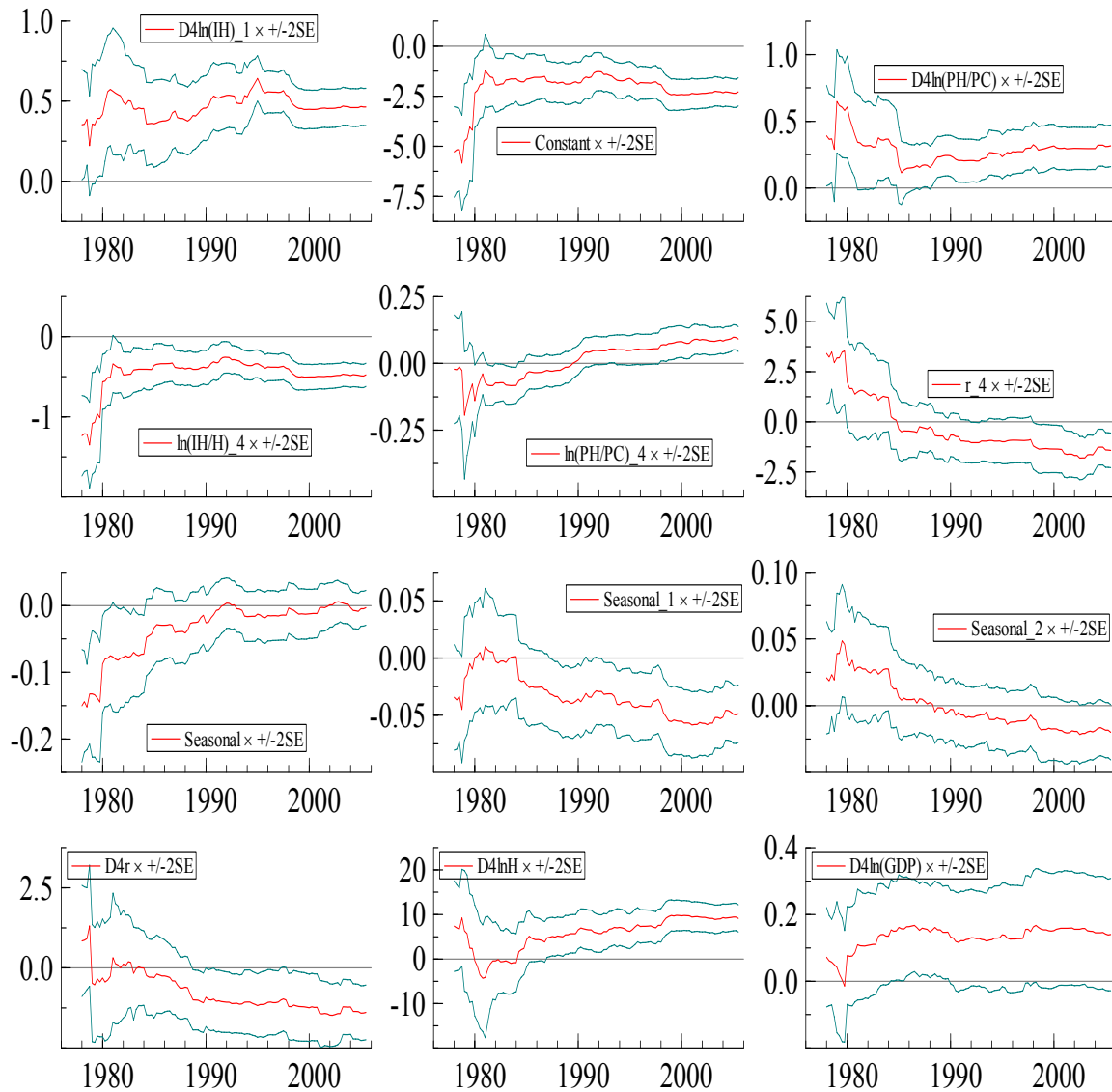
Figure A4.2 show the recursive graphics for the supply side, and figure A4.4 gives the 1-step residuals  $\pm 2SE$ , 1-step chow test, and breakpoint chow test for supply and demand side.

**Figure A4.1**  
**Demand side: Recursive Estimation**

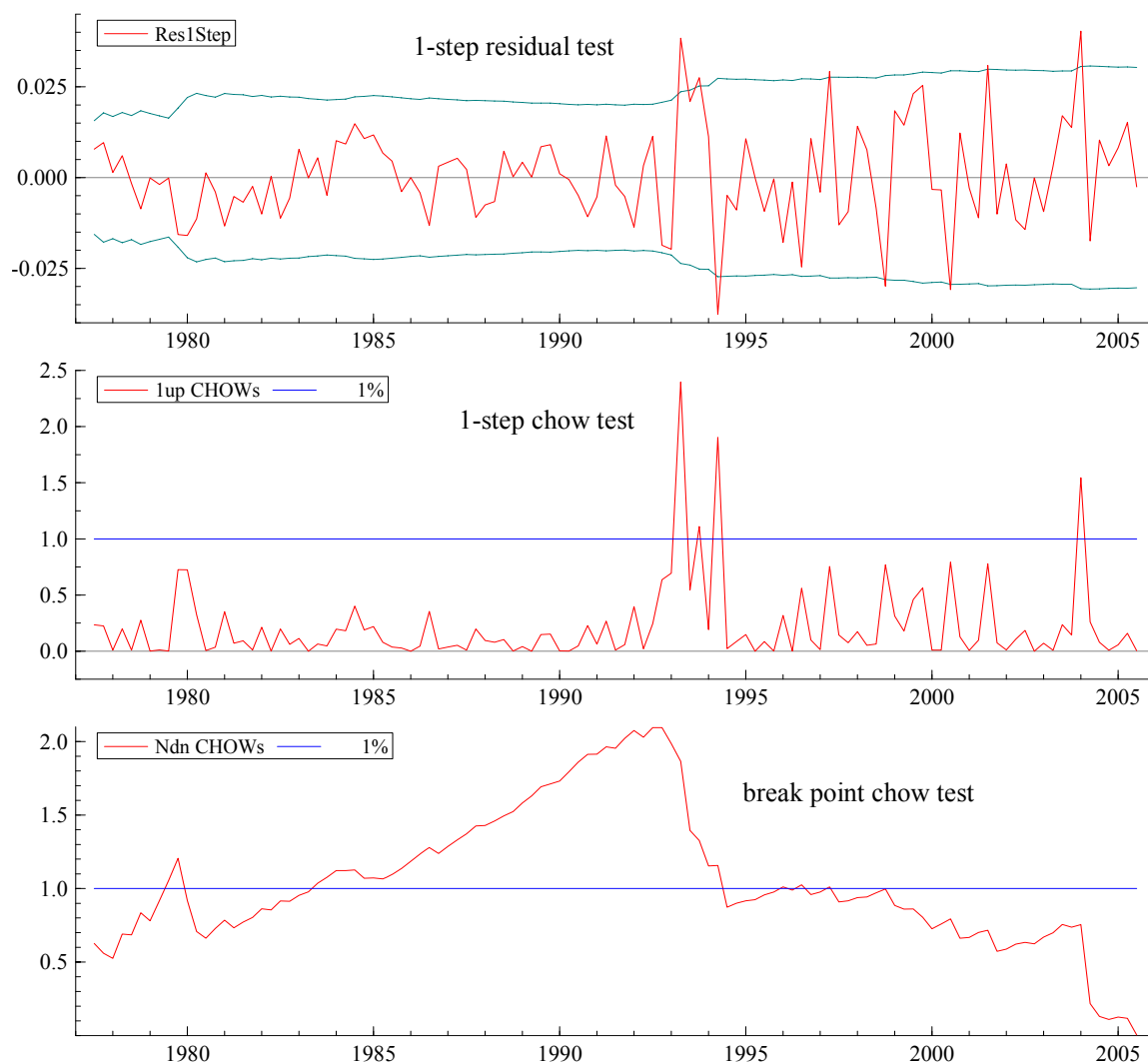


The coefficients of variables like  $\ln(PH/P)_4$  and  $D4\ln(D)$  show non constancy around 1990.  $\ln H_4$  seems to be quite stable after 1980. Other coefficients seem to stay almost constant over the estimation period.

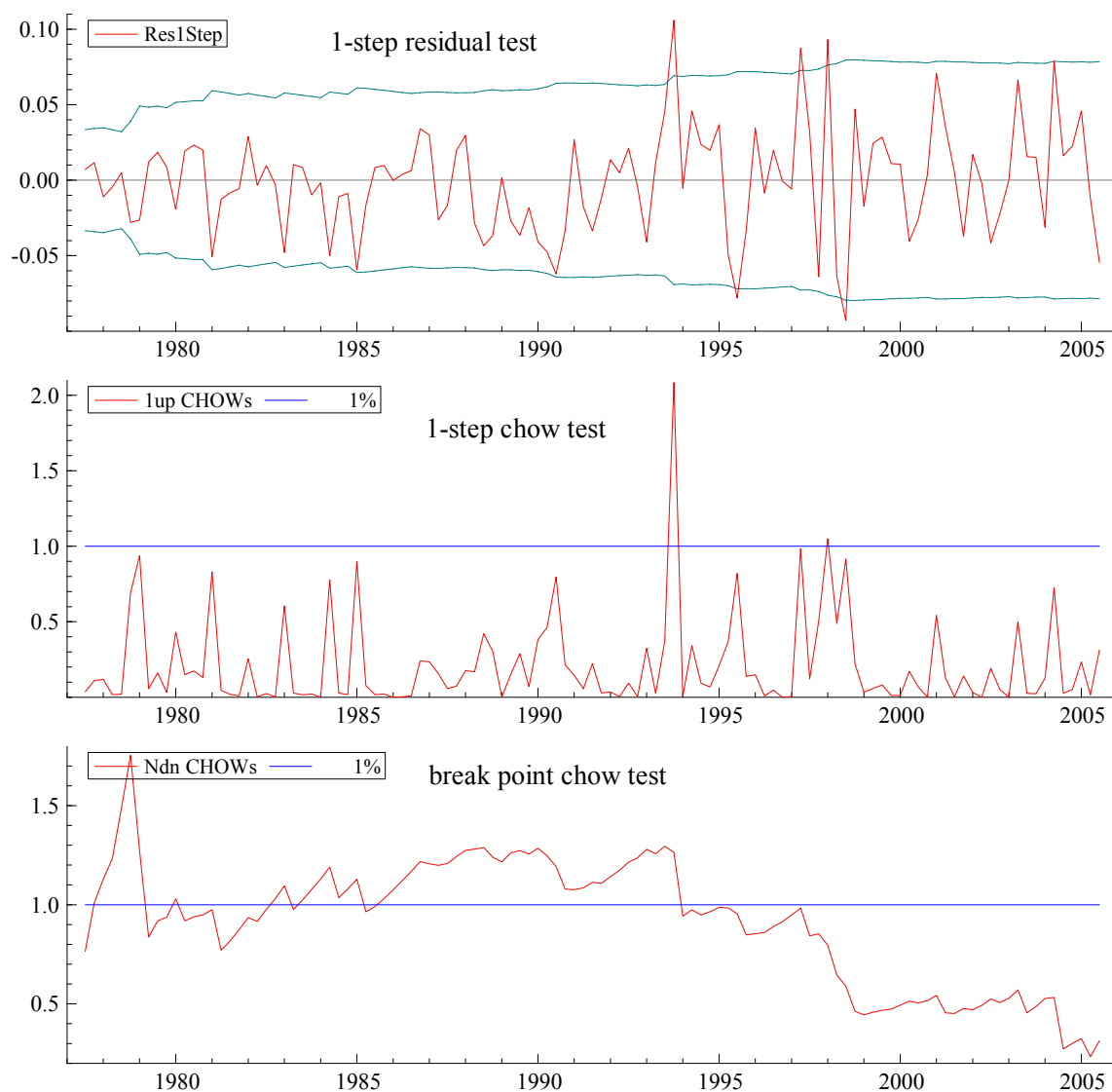
**Figure A4.2**  
**Supply side: recursive estimation**



The coefficients of variables like  $\ln(PH/PC)_4$ ,  $r_4$  and  $D4r$  show non constancy around 1990, i.e. the coefficients lies outside of the previous confidence interval. Similar is the behaviour of coefficients of  $D4\ln H$ , although they lie outside the previous interval a little before 1990.  $D4\ln H$  show seems to be stable after 1986.

**Figure A4.3: Demand Side**

The 1-step residual test shows outliers around 1994. This is confirmed by looking at the 1-step chow test and break point chow test, which also show break around 1994.

**Figure A4.4: Supply Side**

The 1-step residual test shows outliers around 1994. This is confirmed by looking at the 1-step chow test and break point chow test, which also show break around 1994.

